DEVELOPMENT OF AN INTEGRATED LIGHT (MINIMAL) PROCESSING TECHNOLOGY FOR TENDER COCONUT AND TENDER COCONUT HUSK BASED PRODUCTS

By

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THESIS

Submitted in partial fulfilment of the requirement for the degree of

Doctor of Philosophy in Horticulture

Faculty of Agriculture

Kerala Agricultural University

Department of Processing Technology

COLLEGE OF HORTICULTURE

VELLANIKKARA, THRISSUR - 680 656

KERALA, INDIA

2004

DECLARATION

I hereby declare that this thesis entitled **"Development of an integrated light (minimal) processing technology for tender coconut and tender coconut husk based products"** is a bona-fide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, fellowship or other similar title, of any other University or Society.

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CERTIFICATE

Certified that this thesis, entitled **"Development of an integrated light (minimal) processing technology for tender coconut and tender coconut husk based products"** is a record of research work done independently by **Mr.K.V.Subramanian** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to him.

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ACKNOWLEDGEMENT

I have immense pleasure to express my deep sense of gratitude and indebtedness to ***Dr.V.K. Raju****, Associate Professor (Hort.), Department of Processing Technology and Chairman of my advisory Committee for his valuable guidance, critical suggestions, unfailing patience and constant encouragement throughout the investigations for the successful completion of this research programme.*

I express my heartfelt gratitude and indebtedness to ***Dr.Jacob John****, Associate Professor and Head i/c, Department of Processing Technology and member of my advisory committee for his keen interest and encouragement and also for making the facilities available in time for the successful conduct of this work.*

With deep respect I express my profound gratitude to ***Dr.V.K.G. Unnithan****, Associate Professor and Head, Department of Agricultural Statistics and member of my advisory committee for his valuable guidance and suggestion given to me during the course of my research work.*

I am grateful to ***Dr.K.B. Sheela****, Associate Professor (Hort.), Department of Processing Technology and member of my advisory committee for her sincere advice and valuable suggestions extended to me during this study.*

I am happy to record my heartfelt thanks to ***Mr. George Mathen****, Associate Professor, Department of Animal Nutrition, College of Veterinary and Animal Sciences, Mannuthy, for his persistent supervision and suggestions for the successful conduct of this study.*

I would like to express my unforgettable gratitude and indebtedness to Dr.H.P. Singh, the Chairman, Coconut Development Board, Kochi for granting study leave to undertake this programme.

My sincere thanks are due to Dr. Sukumara Varma, S, Associate Dean, College of Horticulture for his valuable guidance and encouragements.

I sincerely thank Dr.P.K. Rajeevan, Associate Professor and Head i/c., Department of Pomology and Floriculture and also Dr.P.K.Valsalakumari, Associate Professor, Department of Pomology and Floriculture for providing facilities and also for their inspiring support and advices.

A special word of gratitude is due to Mr.S. Krishnan, Asst. Professor, Department of Agricultural Statistics for his whole hearted co-operation rendered to me for the statistical analysis of the research data.

The facilities and help provided by Dr.R.V.G. Menon, Director, IRTC, Mundur, and his subordinates working in their mushroom unit are gratefully acknowledged.

I wish to place in record a word of gratitude to Dr. Sushama, Associate Professor, Department of Agronomy for her valuable suggestions and support.

I am indebted to Dr. Joseph Mathew, Associate Professor, University Live Stock Farm, Mannuthy for his kind help in conducting the research work.

The whole-hearted support and advices rendered by Mr.M. Nandakumaran, Professor, Department of Nutrition, College of Veterinary and Animal Sciences, Mannuthy is duly acknowledged.

I am extremely thankful to Dr.B. Mohanan, Associate-Professor, Department of Animal Nutrition, Veterinary College and Research Institute, Namakkal for his kind co-operation for providing laboratory facilities and guidance for conducting the research work.

I thank Mr. Pradeep, Assistant Professor and his office staff, Instructional Farm, Vellanikkara for their kind help for providing tender coconuts required for the study.

Assistance and services rendered by Mr. K.Debnath, Senior Farm Manager and all other staff members of DSP Farm, Vellanikkara are gratefully acknowledged.

My thanks are due to Dr.K. Aravindakshan, Associate Professor and special officer, ATIC, Mannuthy for his sincere help in conducting the pilot study of LP tender coconut in ATIC centre.

I take this opportunity to thank Dr. Pushpalatha, Associate Professor (Hort.), non-teaching staff and co-students, Department of Processing Technology for their whole-hearted help and courtesy extended to me during my study.

I sincerely thank Mr. Joy, JMJ Computers for their excellent and courteous service in the preparation of this thesis.

(K.V. SUBRAMANIAN)

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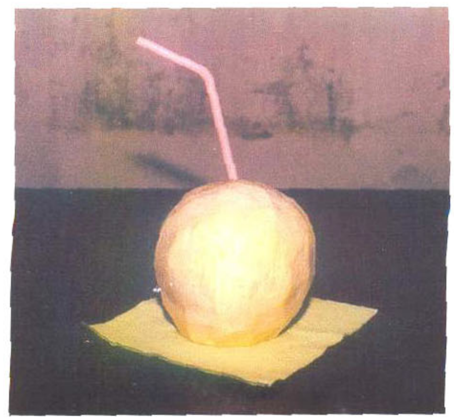
LIST OF ABBREVIATIONS

ADF	-	Acid Detergent Fibre
APCC	-	Asian and Pacific Coconut Community
BE	-	Biological Efficiency
C:N	-	Carbon : Nitrogen ratio
CDG	-	Chavakkad Dwarf Green
COD	-	Chavakkad Orange Dwarf
CSIR	-	Council of Scientific and Industrial Research
CWGH	-	Coconut Water extracted Growth Hormone
FVI	-	Fuel Value Index
GB	-	Ganga Bondom
KMS	-	Potassium metabisulphite
LAI	-	Leaf Area Index
LDPP	-	Low Density Polypropylene
LP	-	Lightly processed
MCH	-	Mature Coconut Husk
NDF	-	Neutral Detergent Fibre
NFE	-	Nitrogen Free Extract
NRS	-	Non-reducing Sugars
PLW	-	Physiological Loss of Weight
RRL	-	Regional Research Laboratory
RS	-	Reducing Sugars
T	-	Tall
TCH	-	Tender Coconut Husk
TC	-	Tender Coconut
TCW	-	Tender Coconut Water
TS	-	Total Sugars
TSS	-	Total Soluble Solids
WCT	-	West Coast Tall

Dedicated to

My Beloved Parents

Introduction



INTRODUCTION

Coconut (*Cocos nucifera* L.) is an important horticultural crop which provides food, oil, beverage, medicine, fibre and a variety of raw materials, for production of an array of products of commercial importance. The crop has significant impact on the national economy besides its influences on economic, social and cultural lives of the people in the country. India is the largest coconut producing country in the world with an annual production of 12821 million nuts from an area of 18.92 lakh hectares (D.E.S., 2003). The crop contributes 7,000 crores of rupees to the GDP and earns about Rs.313 crores as foreign exchange by way of export of coconut products and the crop sustains about 10 million people in the country through cultivation, processing, marketing and trade related activities. The contribution of the crop to the vegetable oil pool in India is six per cent

The major portion of the coconut production is from the four South Indian states viz., Kerala, Tamil Nadu, Karnataka and Andhra Pradesh which comes to 91.4 per cent of the total area and to 90.7 per cent of the total production of coconut. Kerala occupies the premier position with an area of 9.39 lakh ha (50.6%) and a production of 5744 million nuts (42.2%) (D.E.S., 2003).

But now, this regional limitation is only in production and not in consumption. Matured nut, oil and tender nuts are always in demand throughout India irrespective of the seasons.

In India, as much as 48 per cent of the coconut production is used for edible and religious purposes. Then 30 per cent as milling copra, eight per cent as edible copra and the rest for kernel based products and seed nut (Rethinam and Thampan, 2001).

Though only 30 per cent of the total production is consumed for oil production the price of coconut is ruled by the trend in coconut oil market, which always fluctuates wide and erratic. Wide fluctuation in coconut prices had had a negative impact on coconut based industries like desiccated coconut, coconut cream etc. Product diversification with a wider raw material base is, therefore, essential for sustainable development of coconut sector. Popularization of the tender coconut consumption can be a justifiable strategy to ensure regular and assured income from coconut farming.

The tender coconut water, the liquid endosperm, is the most nutritious wholesome thirst-quenching drink that the nature has provided to mankind to fight the sultry heat in the tropics. It also provides sugars, minerals and vitamins in easily digestible form.

Tender coconut still remain an unknown drink to many Indians. The soft drink industry in India shows a phenomenal growth rate of more than 10 per cent in recent years. A wide range of aseptically packaged drinks with artificial flavouring agents and preserved fruit juices are flooded in the market. But, the tender coconut stands out as the only ready to serve natural drink which is available throughout the year with a highly under exploited market potential.

Some efforts have already been made to develop acceptable beverage products from tender and mature coconut water (Pankajakshan, 1986; Krishnankutty, 1994; Srivatsa and Sankaran, 1995; Mathewkutty, 1997). But loss of natural flavour, due to the addition of preservatives and processing methods have affected the acceptability of most of these products.

The major issues in popularization of tender coconut are mainly the bulky nature and the resultant difficulties in handling, transportation and the large quantity of waste collected at the sales points after consumption of tender coconut water, causing serious garbage disposal problems. The average weight of a tender coconut varies from 1.5 kg to 2 kg of which the husk contributes about 60 to 70 per cent.

Popularisation of tender coconut consumption has great scope in India. Though the lions share of coconut production in India is from four South Indian States, tender coconut, the delicious thirst quenching drink, is in demand throughout India. Fortunately, as the hottest period of the year is experienced during various months in South, East, Central and North Indian states, there is a regular and continuous demand for tender coconut throughout the year in one part or other of the country. If entire Indian population consumes 12 tender nut a year the entire coconut production in the country can be consumed by this section alone.

Due to the bulky nature storage and transportation of tender coconut to distant market is difficult and cost prohibitive. Tender coconut water has a strong tendency to undergo rapid biochemical changes after harvest (Srivatsa *et al.,* 1998). When stored under open conditions, the quality of nut water is found to spoil even within 24 hours. Obviously, in such situation consumer satisfaction is not to the desired level.

With this background, the present study was conceived and implemented. The primary aim was to reduce the bulk of the tender coconut, which is contributed by the husk, through minimal processing. This was followed by studies to standardize an attractive appearance for the minimally processed tender coconut that retained the palatability of tender coconut water and the soft sweet kernel meat for a longer period under a low temperature storage environment.

While exploiting the possibility of minimal processing as a tool to make tender coconut a more convenient ready to drink chilled beverage without disturbing it's natural packaging considerably, tender coconut husk turned out to be the major by-product. On an average, one kilogram of tender coconut husk could be trimmed off from each tender coconut during minimal processing. This posed the need for undertaking studies on value addition to the tender coconut husk.

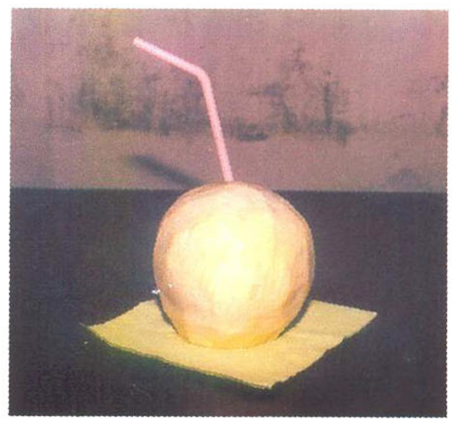
In the light of the aforementioned issues the present study on "Development of an integrated light (minimal) processing technology for tender coconut and tender coconut husk based products", was undertaken with the following objectives.

I. To develop a technology to make the tender coconut a ready to serve natural, chilled beverage.

II. To develop technology for value addition of tender coconut husk, viz:
   a) Composting fresh tender coconut husk
   b) Producing silage for cattle from the tender coconut husk.
   c) As growing media component for anthurium
   d) As growing medium for mushroom
   e) As fuel and estimation of calorific value of tender coconut shell

III. Pilot testing (consumer response) of the light (minimal) processing technology for tender coconut.

Review of Literature



2. REVIEW OF LITERATURE

Introduction of minimal processing technology for tender coconut to make it a safe and convenient cool drink may have a wide scope and adaptability in soft drink industry in India. Besides,the major thrust area of minimal processing of tender coconut, integrating the processing of tender coconut husk for converting the same into some useful products will make tender coconut business more remunerative.

Research findings already reported by various workers on tender coconut, its processing, storage, quality and other related aspects are reviewed hereunder.

2.1 CYTOLOGY OF TENDER COCONUT WATER

The coconut water is considered as a dynamic living system with unique biochemical properties. Several authors have tried to study the cytological peculiarities of coconut water (Cutter *et al.*, 1995, Kumar *et al.*, 1995). Water of tender coconut is technically liquid endosperm and the chemical composition of it varies depending on maturity, variety, soil and climatic conditions. The major constituents of coconut water are sugars, minerals and minor ones are fat, protein and other nitrogenous substances (Subramanian and Swaminathan, 1959).

2.2 COMPOSITION OF TENDER COCONUT WATER

Coconut water contains quite a number of substances and their composition is altered markedly with the stages of maturity (Pandalai, 1958; Jaylakshmi *et al.*, 1988 and Shivasankar, 1991) (Appendix - 3).

The liquid endosperm played a vital role in the fruit development by acting as a reservoir of precursors to synthesise fruit constituents. In addition to minerals and sugars coconut water also contain, amino acids and vitamins (Gonzalez, 1993). (Appendix – 5 & 6).

Krishnankutty (1994) reported that mature coconut water contained 5.4 per cent TSS, 2.0 per cent soluble sugars, 0.5 per cent minerals, 0.1 per cent protein, 0.1 per cent fat, 0.060% acidity and pH 5.2. The corresponding figures of tender coconut water of seven month maturity were, 6.5, 5.7, 0.6, 0.01, 0.07, 0.120 and 4.5.

2.3 SPECIFIC GRAVITY OF COCONUT WATER

Gangully and Nambiar (1953) studied the pattern of density of coconut water from the initial stage to full maturity. They reported that water appeared in the nut during third month and it had a density of 1.13 g/cc and it showed gradual decrease to 1.101 g/cc at twelfth month of maturity. The minimum density was recorded at fourth month with 0.96 g/cc.

2.4 BIOCHEMICAL COMPONENTS OF COCONUT WATER

2.4.1 Carbohydrates

Coconut water at different stages of development of the nut as early, medium and full ripe stage were analysed and found that there was an accumulation of invert sugars in the water. During the second stage more sucrose (cane sugar) appeared in the water. In the ripening stage invert sugar decreased and cane sugar increased slightly. The total sugar content was found to decrease from 5.5 per cent at drinkable stage to about two per cent at ripe stage, mostly non-reducing sugars.

Nathanael (1952) reported that nut water at four month stage, when water cavity has just formed, contained one per cent sugar, entirely reducing sugars and this reached at four per cent at fifth month and only with reducing sugars. The maximum sugar content was reached to five per cent at the *kurumba* stage at the seventh month of development, and beyond this stage sugar concentration fall steadily.

During the stages of fruit development, the sugar in the sap of the inflorescence axis entering the fruit undergoes complete conversion from sucrose to glucose and fructose by the action of invertase present in stalk (Balasubramanian, 1983; Balasubramanian and Alles, 1989).

Variation in the glucose content of six month old tender coconuts harvested from Tall and Dwarf forms of Andaman coconut were investigated by Nair and Sadanandan (1983). They reported that Tall and Dwarf forms did not show any significant differences with respect to glucose content of coconut water. The total variation with age ranged from 2.0 to 6.9 per cent only. Krishnamarar (1957) also reported appearance of non-reducing sugars after sixth month and at full ripe stage.

Chickasubbanna *et al.* (1990) found that both reducing and non-reducing sugars increased between sixth and ninth months of maturation. According to Jayalakshmi *et al.* (1988) two major changes in the profile of sugars during maturation were the steep fall of total sugars and the disappearance of reducing sugars (Appendix-4).

Sugar content in six months old tender coconuts of eight varieties of coconut were evaluated by Louis *et al.* (1983). They reported that reducing sugar content varied from 2.25 to 6.10 per cent and non-reducing sugar from 0.04 to 1.68 per cent. They also found that when the nut size was small for example Ayiramkachi and Local Dwarf green, the tender coconut registered relatively higher content of reducing sugars (6.10 and 5.55 per cent respectively).

Rosario *et al.* (1984) using HPLC techniques analysed the coconut water from nuts of mature stages. HPLC elution peaks were observed for glucose, fructose, sucrose, sorbitol, mannitol and oligosaccharides with degree of polymerisation of 3, 4, 5 and >5. For coconut water from mature fruits, the total concentration of sucrose, glucose and fructose was 3.0 gram per litre, that of galactose, xylose and mannose was 2.3 gram per litre and mannitol concentration was close to 0.3 gram per litre.

HPLC technique was used by Balachandran *et al.* (1987) for estimation of soluble sugars in coconut endosperm of mature stage. They observed that the profile of sugars of coconut water indicated that it contained the highest proportion of glucose and lowest proportion of sucrose compared to those of other regions of the coconut endosperm. They reported that coconut water contained only two per cent sugars and the relative concentration of the major sugars of coconut water and of the innermost layer of the kernel were similar. The average composition of different sugars in coconut water include: ribose and rhamnose in traces, fructose 2.88 per cent, glucose 37.98 per cent, sucrose 58.39 per cent, maltose 0.28 per cent and unidentified sugars in traces.

Traces of an unidentified trisaccharide co-eluting with rafinose (galactose-glucose-fructose) and an unidentified tetrasaccharide co-eluting with stachiose have been isolated from the nut water of Dwarf and Tall varieties respectively (Enonuya, 1988). White *et al.* (1989) had isolated from the liquid endosperm of mature coconuts, a polysaccharide presumably an arabinogalactan, with a molecular weight exceeding 500,000 daltons and composed predominantly of galactose and arabinose with minor amounts of mannose and glucose. Two smaller polysaccharides containing significant amount of xylose or mannose and lesser amounts of arabinose and another polysaccharide composed exclusively of uronic acid residues have also been reported.

Kalathiya and Sen (1991) reported that the reducing sugar content did not significantly change with age of nuts (6, 8, 10 or 12 months) of cv. Dwarf Green under coastal Gujarat condition. Total sugar content was highest at six months (5.95%) and lowest at 12 months (2.65%). The highest TSS occurred at tenth month (6.16%).

Dhamodaran *et al.* (1993) evaluated seven month old tender coconuts for sugar content in twelve cultivars. The cultivar Chowghat Orange Dwarf (COD) registered the maximum values for total sugars (7.0 g) and reducing sugar (4.7 g).

There is a progressive decrease in the quantity of nut water as the nut ripen. The chemical composition and volume of nut water change during maturation. Coconut water has vital role in the biosynthesis of fat in the kernel as well as in the development of the germination of the nut. Maximum volume of water have been reported in six months old nut by many workers (Krishnamarar, 1957; Jayalakshmi *et al.*, 1988 and Srivatsa *et al.*, 1998).

Shivasankar (1991) reported that coconut water found in small quantities in the third month of development of the nut and reaches maximum in the eighth month and declines thereafter as the nut ripens. The drink is at its optimum level of acceptability and economic viability when the nuts are of six month maturity (Srivatsa and Sankaran, 1995).

2.4.2 Protein

Coconut water contains small amounts of protein. The nitrogen and total protein content of coconut water increased gradually with maturation (Chikkasubbanna *et al.*, 1990). The percentages of arginine, alanine, cystine and serene in the protein of tender coconut water are reported to be higher than those in cow's milk (Thampan, 1993; Gonzalez, 1993) (Appendix-5). Since it does not contain any complex protein, the danger of producing shock to the patients is minimised. The protein content of nut water increases from 0.13 per cent to 0.29 per cent while it decreases in the kernel from 8.3 per cent at the eighth month to 6.2 per cent at maturity (Shivasankar, 1991). In the immature nut water, about 70 per cent of the free amino acids are made of glutamine, arginine, aspargine, alanine and aspartic acid while alanine, γ aminobutyric acid and glutamic acid constitute about 75 per cent of the free amino acids of mature nut water (Shivasankar, 1991). In a study conducted by Poduval *et al.* (1998) it was found that in most of the cultivars maximum free amino acid content was in the water of seven month old nut.

During fourth month of development, coconut water contained 0.049 per cent protein which changed to 0.088 and 0.123 per cent respectively in the seventh and eighth month and recorded a maximum of 0.2 in the twelfth month (Subramanyam and Swaminathan, 1959). Mondal *et al.* (1970) reported that DNA, RNA and protein present in coconut water were found to be in the soluble form and not associated with any organelles i.e., nuclei, mitochondria or ribosomes, DNA and RNA seemed to be degraded or of low molecular weight.

The developing coconut fruit contained a variety of nitrogenous substances of which free amino acids constituted a major part (Tulecke *et al.*, 1961). Pillai (1964) showed that in the ripening nut the free amino acid content in coconut water increased from four mg per 100 ml to 16 mg per 100 ml. Proline content was highest in the immature nut and decreased with maturity leaving only a trace in the water of the mature nut.

In the liquid endosperm of the immature coconut (5-6 months), the concentration of the total amino acids was less than that in the mature coconuts (Gunawardena, 1973).

2.4.3 Enzymes

Wilson and Cutter (1952) observed acid phosphatase activity in nut water. Janistyn (1989) reported CAMP dependent protein kinase activity in nut water.

2.4.4 Vitamins and minerals

Tender coconut water contains both ascorbic acid and vitamins of B group (Appendix-6). The concentration of ascorbic acid ranges from 2.2 to 3.7 $\mu g\ ml^{-1}$. which gradually diminishes as the kernel surrounding the water begins to harden.

Desikachar (1952) reported that coconut water contained essential minerals like sodium, potassium, calcium, magnesium, iron, copper, phosphorus, sulphur and chlorine. It also contained vitamin C and B groups. Later, Shivanandiah (1970) reported that tender coconut water contained not only glucose but also other nutrient elements such as nitrogen, phosphorus, sulphur, sodium, copper, iron, potassium, calcium, fat, sugars, amino acids and vitamins, which varied in proportion according to the age of the coconut.

Dhamodaran *et al.* (1993) compared 12 coconut cultivars for their tender coconut water quality. They found that sodium and potassium content was low (20 and 2003 ppm respectively) in cultivar CDO which was rated top for tender coconut water.

2.4.5 Potassium

Vijayan *et al.* (1977) estimated the potassium content in tender coconut water (6-7 month age) and ripe nuts. The variety Fiji registered the highest potassium content of 0.360 g per 100 ml. It was the least in Goa variety (0.232 g/100 ml). In ripe nuts, the potassium content varied from 0.200 to 0.280 g per 100 ml water. The highest amount was recorded in Fiji and the lowest was in Ganga Bondam.

2.4.6 Lipids

In general, the relative proportions of fatty acids (up to C_{14}:O) increased during maturation while a corresponding decrease in the higher unsaturated fatty acids occurred. The most characteristic feature was that the content of lauric acid (C_{12}:O) in both nut water and kernel rapidly increased with maturity up to 45 per cent of the total in the mature nut while the contents of most other fatty acids remained far below 20 per cent (Kartha *et al.*, 1959). The fat content of the nut water showed a gradual decrease up to the tenth month and rose gradually thereafter reaching a maximum in the twelfth month. Four of the fatty acids in nut water, C_{14}:O, C_{15}:O, C_{16}:O and C_{17}:O which were present in the early stages disappeared as the nut matured whereas the content of short chain fatty acids, C_6:O, C_8:O and C_{10}:O which were present in negligible levels initially, rose with maturity in both the water and kernel (Jayalakshmi *et al.*, 1988).

Water of unripe nut contains 0.12 per cent fat and the water of ripe nut contains 0.15 per cent fat; the fat content in the kernel of the unripe nut being 1.4 per cent. The reduction in sugar content is also associated with an increase in the oil percentage of the kernel (Subramanyam and Swaminathan, 1959).

2.4.7 Silica

Pillai (1967) reported the presence of traces of silica in coconut water. He found that tender coconut contained less silica than the matured ones.

2.4.8 Phytin

Phytin was reported to be present in coconut water and its role in supplying phosphate for synthesis of nucleic acids has been demonstrated (Roychaudhury and Biswas, 1962).

2.4.9 Effervescence and flavour

Tender coconut water is reported to be under hydrostatic pressure, which might facilitate the dissolution of CO_2 in water. Therefore effervescence appears in the water on opening a tender coconut at proper stage. Depletion of water on maturation causes an empty space into which the gases escape and therefore effervescence is usually not observed in the matured nut water (Jayalakshmi *et al.*, 1988). It has been reported that the gas occupying the free space in the ripe nut is essentially nitrogen (Edirweera, 1996). The characteristic and pleasant flavour of tender coconut water is contributed by delta lactones, which are found to diminish slowly with maturity. It is this labile flavour which is most difficult to preserve and which is sought after by the consumers (Srivatsa *et al.*, 1998).

2.5 FLORAL BIOLOGY OF COCONUT

Inflorescence of coconut begins as a minute protuberance at the axil of clasping petiole (Juliano, 1926). Interval of the production of inflorescence varies with genotype and management. Theoretically every leaf axil should have one spadix but some are aborted due to various reasons. Production of even 20 leaves and 18 spathes per year is reported in vigorous, middle aged super palms.

In a study Vijayaraghavan *et al.* (1993) found that reproductive phase was more active in April-September season (65-70%) in Thanjavur district. Hybrids (MDY x ECT and ECT x MDY) were producing higher number of spadices (16.2 to 14.7 respectively) in a year.

2.5.1 Pattern of development of the nut

The fruit development in coconut, from the time of initiation of inflorescence primordium to full maturity of the nut, could be divided into two major phases, namely, pre-fertilisation phase taking about 32 months and the post-fertilisation phase continuing for another 12 months, mainly by cell enlargement which was associated with the accumulation of food reserves (Patel, 1938). Coir fibre strands could be distinctly seen in the tender coconut stage itself and their growth both in length and thickness and lignification were practically complete by tenth month (Menon, 1942).

The female flowers borne on the bunches took normally about 12 months to develop and grow to maturity. Ganguly and Nambiar (1953) had traced the physical changes occurring during this period.

Nathanael (1966) described the changes during the development of the nut. He suggested that when an average healthy palm was stripped into its components, it should be possible to isolate about 44 developmental stages of the floral branch. These ranged between the initials of the primordial inflorescence (situated as a minute cone like protuberance in the axil of the fourth rudimentary leaf from the growing point) and the cluster of ripe green nuts as harvested. These 44 stages were categorised as follows:

i. stage 1 to 10 : Spathes very rudimentary, undifferentiated and tender
ii. stage 11 to 29 : Spathe has just split open
iii. stage 30 to 44 : Ripe green cluster, with nuts containing the rudimentary embryo

On the basis that a new spathe is appeared in every 25 days it would take the primordial inflorescence (Stage 1).

a) 1,100 days (approximately three years) to reach maturity (Stage 44)
b) 250 days (approximately eight months) to reach stage 11, and
c) 750 days (approximately two years) to reach stage 31.

The kernel first made its appearance as a jelly like substance at stage 37 in the series. This would correspond to an age of about five months from the time of opening of the floral branch.

The growth of the fruit began, immediately following fertilisation, with a rapid development of the pericarp at the basal region, which remained soft and white until the fruit was nearly mature. The endocarp is already differentiated as a soft, creamy, white structure long before the time of fertilisation.

The cavity inside the nut differentiate itself in the second month and increase in size reaching maximum size at sixth month with full water. The meat starts forming in sixth months and water content decrease with increased kernel growth (Marar, 1957).

The endosperm of coconut developed as a coenocytic liquid containing many free nuclei and some cells (Cutter *et al.*, 1995). The cells coalesced towards the periphery of the embryo sac. Additional cells were formed when free nuclei adhered resulting in the formation of cellular endosperm. In the mature coconut, the liquid which was of cytoplasmic in origin (Kumar *et al.*, 1995) did not contain free nuclei or free cells (Cutter *et al.*, 1995). The shell began to form during the fourth month of nut development and continued to grow up to the twelfth month. The kernel was the last component to begin formation in the seventh month and its growth continued up to eleventh month when maximum value of dry weight was achieved. The growth of the kernel was of a 'blitz' nature for the first two or three months during which time it gathered most of its raw material. The reddish testa, which assumed a brownish tint when mature, was laid down long before the formation of the kernel. Its growth was proportionately greater than that of the kernel during the early stages (Cutter *et al.*, 1952; Kartha and Narayanan, 1956).

2.5.2 Origin and development of stony layer of the fruit

Before the ovules are formed, the pericarp wall was homogeneous in structure and was composed of isodiametric cells. As the loculi of the ovary developed, and just before the ovules were formed, the pericarp wall undergoes triple differentiation. The outermost layer of cells became squarish to elongated horizontally. The hypodermal cells were isodiametric. The cells within the hypodermis were large, and the innermost part of the pericarp was composed of small rectangular to squarish cells. The pericarp, then, had undergone differentiation long before the ovules were formed into (a) an outer single layer of squarish to elongated cells, the exocarp; (b) the large isodiametric cells of the mesocarop; and (c) the small isodiametric cells of the endocarp. Lignification of the endocarp proceeded from the stigmatic point of the fruit toward the basal region, and from the middle to the sides of the layer of the endocarp (Winton 1901; Juliano, 1926).

2.6 PHYSICAL COMPOSITION OF TENDER COCONUT FRUIT

Gangully and Nambiar (1953) reported a detailed account of the physical composition of the coconut from the fruit set to twelfth month. They studied growth features of the coconut at monthly intervals and reported that during sixth and seventh month the features of the developing coconut were as follows:

Physical composition of the coconut

	6th month	7th month
Average weight of nut	1566.60 g	1617.75 g
Average volume of nut	1585.00 cc	1662.50 cc
Average lateral circumference	42.90 cm	44.10 cm
Average weight of water	258.00 g	218.00 g
Average volume of water	253.00 cc	210.05 cc
Average density of water	1.03 g/cc	1.04 g/cc
Average thickness of meat	0.10 cm	0.40 cm
Average weight of meat	37.50 g	67.00 g
Average weight of husk	1154.00 g	1210.00 g
Average weight of shell	390.00 g	384.10 g

Further, they reported that the weight of the nut was highest during the eighth month (2205.13 g) which subsequently declined steadily till maturity (1418.5 g). The nut water first appeared during the third month of development and increased to its maximum volume in the sixth month and then gradually declined. The volume of water at the twelfth month was only 100 cc in the normal nuts. The husk reached its maximum weight in the eighth month (1771 g) and declined to 938 g at twelfth month. However, the pattern of development of the meat was different from most of the other components of the nut. The meat started appearing during the sixth month and steadily increased in content and reached the maximum weight of 223 gram in the twelfth month. But the maximum thickness for the kernel was recorded in the tenth month (1.76 cm) which reduced to 1.20 cm during the twelfth month.

Reddy *et al.* (1980) reported the average percentage composition of coconut as pith and fibre 27.40; shell 22.18; water 15.10; kernel 36.32. They assessed the percentage constituents of ten varieties of coconuts viz. Guam, San Ramon, West Coast Tall, Andaman Ordinary, Laccadive Ordinary, Laccadive Micro, Dwarf Green, Fiji Island

Tall, Dwarf Orange and Ganga Bondam. The characters assessed were weight of coconut, fibre and pith, shell, water, kernel, moisture content of extracted oil. The authors observed variations in the share of the different constituents of nuts of the different varieties.

Reddy *et al.* (1980) analysed eleven coconut varieties, viz., Tall x Dwarf, Dwarf x Tall, Laccadive Small, Laccadive Ordinary, Andaman Ordinary, East Coast Tall, Java Giant, Cochin China, Fiji, Philippines and Java for studying the percentage composition of exocarp, mesocarp, water, endocarp and endosperm contents and oil and free fatty acid contents of kernel. They observed marked variations among the varieties and among the mature nuts of the same variety. The average values were exocarp 13, mesocarp 33.5, water 4.0, endocarp 22.5 and endosperm 27 per cent and oil and free fatty acid content of endosperm 67.3 and 0.6 per cent respectively. Singh (1980) stated that the percentage of each component making up the whole nut was variable, but the average figures were indicated as about 50 per cent husk, 14 per cent shell, 26 per cent meat and ten per cent water.

Sarangamath *et al.* (1983) studied the variability in coconut cultivars for nut characters. The cultivars included in the study were Spicata, Ganga Bondam, Fiji, Kaithahalli, Laccadive Dwarf, Andaman Dwarf, West Coast Tall, Philippines, Laccadive Ordinary, SS Green and Kappadam. Fully matured coconuts were air dried at room temperature to yield copra. Variations were observed among varieties for weight of husk, weight of nut, weight of copra and moisture content of copra.

The fruits of local coconut cultivars from the Bhubaneswar region were examined at monthly intervals up to 12 months after fertilisation by Panda and Maharana (1989). Fruit weight, water content and husk weight increased up to eighth month and then decreased. Kernel development began in the eighth month, the kernel increasing to the maximum weight of 168 gram in the eleventh month. Copra oil content increased with fruit age to the maximum of 73 per cent in the twelfth month.

A study of nut development in cv. Dwarf Green under coastal Gujarat conditions revealed that greatest fruit length (27.25 cm), fruit breadth (15.78 cm), fruit girth (46.90 cm), fruit volume (1950.50 ml) and kernel weight (257.5 g) were observed in twelve month old nuts. In another study fruit weight was highest (2255 g) in ten month old nuts (Kalathiya and Sen, 1991).

2.7 VARIETAL SUITABILITY FOR TENDER COCONUTS

Davis (1962) opined that dwarf cultivars of coconut were valued more for their tastier water compared to talls. He also stated that King Coconut of Sri Lanka had much sweeter water than Ganga Bondam.

Ghosh (1978a) reported that hybrids of Dwarf variety produced tender coconuts of high quality, quite suitable for drinking purpose.

Dhamodaran *et al.* (1993) evaluated 12 coconut cultivars to find out a suitable tender coconut cultivar. Biochemical evaluation indicated that COD had the maximum amount of total sugars (7.0 g/100 ml) and reducing sugars (4.7 g/100 ml) and low sodium and potassium content (20 and 2003 ppm respectively). Scores and weightage were given for tender coconut characters following Anderson's method and maximum score of 73 was given to COD. Four cultivars selected based on biochemical evaluation were subjected to organoleptic test by seven tasters following a non-parametric statistical method. This study also confirmed the superior tender coconut quality of COD.

Louis *et al.* (1983) evaluated eight coconut varieties for their tender coconut characteristics. They studied the sugar content, volume of coconut water and weight of meat in the selected nut and recommended that the varieties Semi-Tall Red and Semi-Tall Green were superior based on the volume of coconut water combined with high sugar content. The other varieties included in the study were Cochin China, East Coast Tall, Tall x Dwarf Green, Semi-Tall Yellow, Ayiramkachi and Local Dwarf Green.

Cochin China, Ayirankachi, Semi-Tall Red, Semi-Tall Orange and Malaysian Yellow were recommended as varieties suitable for tender coconut under Tamil Nadu conditions (Tamil Nadu Agricultural University, 1994).

Raveendran (1996) discussed various aspects of coconut breeding in relation to quality improvement including that of tender coconuts. Dwarf x Tall combinations were better in yield and tender nut quality.

Chinnaraj (1997) evaluated fourteen hybrids and cultivars of coconuts for suitability for tender coconuts. Malayan Dwarf Yellow, Malayan Dwarf Orange, among Dwarf; Malayan Dwarf Orange x Ganga Bondam, Malayan Dwarf Green x Phillippines, among hybrids and East Coast Tall and West Coat Tall among talls were ranked as superior for tender coconut qualities. Thampan and Venkatachalam (2000) observed the varieties WCT, CDG, COD and D x T hybrid are equally suitable for tender coconut. Among these varieties there is a general preference for Dwarf Orange as it is comparatively sweeter and handy due to smaller size. Harvesting of tender coconut from Dwarf is also easy due to its short stature.

2.8 STAGE OF MATURITY FOR HARVESTING TENDER COCONUTS

Stage of harvest in tender coconut is very critical. Immature tender coconuts are less sweet and sometimes astringent, whereas over mature coconuts are bland in taste but sometimes with an oily note. The tender coconut water at optimum maturity is a pleasant drink with a cool, refreshing effervescence.

Marar (1957) opined that nuts to be used as tender coconuts were best harvested when they were 6-7 months old. At this stage volume of nut water was maximum and it contained the highest sugar and amino acid concentration. Pandalai (1958) stated that tender coconut was used for enjoying the sweet and delicious liquid as a drink, when it was approximately seven months old. Davis (1962) stated that seven month old tender coconuts were best for drinking. At this stage the water had maximum glucose content and the cane sugar in traces which gave it better palatability. Similar observations were reported by Ghosh (1978b) also.

Panda and Maharana (1989) conducted growth studies in local coconut cultivars of Bhubaneswar and concluded that seven to eight month old coconuts were good for harvest as green (tender) coconuts. Chinnaraj (1997) fixed seven months as the optimum age for harvesting tender coconuts.

Edirweera (1996) has reported that the water from nuts at the *Kurumba* stage (about 220 days old) is best suited for drinking as a beverage since glucose is highest during this stage besides maximum volume of water. Eventhough both tender coconut water and mature coconut water contain negligible quantity of fat (0.12% and 0.15% respectively), the fat content in the kernel increases on maturation. During the 6-7 month stage, the major fatty acids in coconut water are linolenic (Omega 3), oleic and arachidic. The climatic condition, soil condition and the genetical characters are found influencing the chemical composition of nut water.

2.9 USES OF COCONUT WATER

The tender coconut is in use from time immemorial as a thirst quenching delicious natural beverage in India. It is rich in minerals, sugars, vitamins and it is used in many ways including nutritional, medicinal and such other purposes.

2.9.1 Medicinal properties of coconut water

Coconut water is reported to be sterile and non-hemolytic and recommended for intravenous administration (Majundar, 1951). It is laxative, diuretic and claimed to destroy intestinal worms (Desikachar, 1952; Pandalai, 1958; Davis, 1962; Ghosh, 1978a).

Tender coconut water tones up the heart muscles, increases heart rate, and helps in maintaining body warmth in cases of dehydration. It increased the blood circulation in the kidneys and caused profuse diuresis (Shivanandiah, 1970; Rethinam, 1982; Reddy, 1986). It is a natural isotonic beverage with the same level of electrolytic balance as in human blood.

Ayurveda says "It is unctuous, sweet, increasing semen, promoting digestion and clearing the urinary path". Numerous medicinal properties reported are:

- Good for feeding infants suffering from intestinal disturbances
- Oral rehydration medium
- Contains organic compounds possessing growth promoting properties
- Keeps the body cool

- Application on the body prevents prickly heat and summer boils and subsides the rashes caused by small pox, chicken pox, measles, etc.
- Kills intestinal worms
- Presence of saline and albumen makes it a good drink in cholera cases
- Checks urinary infections
- Excellent tonic for the old and sick
- Cures malnourishment
- Diuretic
- Effective in treatment of kidney and urethral stones
- Can be injected intravenously in emergency case
- Found as blood plasma substitute because it is sterile, does not produce heat, does not destroy red blood cells and is readily accepted by the body.
- Aids quick absorption of the drugs and makes their peak concentration in the blood easier by its electrolytic effect
- Urinary antiseptic and eliminates poisons in case of mineral poisoning
- An antidote to ward off the ill effects of tobacco and alcohol (Rethinam and Nandakumar, 2001).

TCW can be transfused directly from the nut as a substitute for normal saline in dehydration caused by various gastro-intestinal disorders. Running the fluid at the rate of 20 to 25 drops per minute by inserting the sterilised transfusion set after painting the chopped portion with tincture of iodine helps the fluid to pass through transfusion filter and reduces the risk of needle block. But transfusion should be restricted to emergency cases and should not be repeated because of the probabilities of the formation of antibodies. A study in the Philippines showed that coconut water from nine month old nut could be safely injected into healthy human subject. It is reported that patients with weak kidneys, however, may not be able to tolerate high doses of fluid due to its high potassium content. The intravenous use of coconut water needs to be done with special care and diligence (Edirweera, 1996).

A technology for the enzymatic production of dextran and high fructose syrup from sugar supplemented coconut water has been developed in Philippines. The dextransucrase, which had been produced by a local isolate of *Leucorostoc mesenteroides*, polymerised the glucose and sucrose into dextran and freed fructose at high conversion efficiency and degree of purity. The use of coconut water as a vehicle resulted in the production of low molecular weight dextran, which can be used directly as blood plasma extender (Lozano *al al.*, 1991).

In a study conducted in Thailand among the patients with diarrhoea, it was found that coconut water would be absorbed by the system more easily than other soft drinks such as cola, sprite etc. (Barana *et al.*, 1982).

2.9.2 Coconut water as a substrate for microbial culture

Several authors have reported the effectiveness of coconut water as a substrate for microbial cultivation (Hipolito, 1963; Hipolito *et al.*, 1965; Serrano *et al.*, 1967; Aliwalas *et al.*, 1968; Paca and Cancino, 1973; Sierra and Velasco, 1976; Del Rosario *et al.*, 1989; Dangar *et al.*, 1991; Krishnankutty, 1994; Poduval, 1994).

2.9.3 As a component in tissue culture medium

Coconut water has auxinic or growth promoting properties and is liberally made use of in the tissue culture techniques. Coconut water is used as a substitute for potato dextrose agar and malt extract agar, in laboratory culture media (Quimio, 1984). It is also a good culture medium for bacterial and fungal organisms because of its high sugar content as well as the contents of nitrogen, potassium, calcium, magnesium and iron in it.

National Institute of Biotechnology and Applied Microbiology, Philippines has developed an improved technology to extract growth hormones from coconut water. Coconut water contains a diversity of biologically active compounds of which most notable are growth regulators or growth hormones such as auxins, gibberellins and cytokinins. These are essential but expensive, biochemicals used in tissue culture and cell formation. The process developed by the Institute is a direct extraction procedure using a volatile organic solvent that can be readily recovered or recycled for the next extraction. Research results also showed that coconut water extracted growth hormones (CWGH) induced early root development, early nodulation and increased plant growth in legumes, rice and corn. In a study conducted in Philippines by Mamaril and Lopez (1997), it was found that CWGH extract can be used judiciously for the mass propagation of different orchid species like *Dendrobium* sp. *Vanda sanderiana* etc.

2.9.4 Products from tender coconut water

Srivatsa and Sankaran (1995) reported that the tender coconut water can be packed in polymeric pouches and aluminium cans of 200 ml capacity. As tender coconut water was highly susceptible to heating it was subjected to minimum heating and additives like nisin were employed to achieve commercial sterility. The pH of the TCW was maintained in the acceptable range of 4.5-5.2. Use of sweetening agent, to get the uniformity in taste, was also suggested. The product had a storage life of six months under refrigerated condition.

FAO has patented a technology for bottling tender coconut (developed by an Italian technologist) water for marketing as a sports drink. In this technology water content is modified through microfiltration to approximate to the vitamins and energy content of major sports drink (Rethinam and Nandakumar, 2001).

Miracle Food Processors International Ltd., Perinthalmanna, Kerala, India is producing concentrated tender coconut water by adopting a German technology which apply reverse osmosis technique. The product has a minimum of six month storage life. Ten litres of fresh TCW will produce 800 g of concentrate (Rethinam and Nandakumar, 2001).

2.9.5 Products from mature coconut water

Krishnankutty (1994) reported that at R.R.L. Trivandrum (CSIR) a technology was developed for processing mature coconut water into a soft drink which had a good consumer acceptability

Soft drink from coconut water has already been developed in Philippines, Thailand and Singapore and is available both as carbonated and non-carbonated or as coconut lemonade (Reddy, 1986).

Works on microbiological aspect of processing and diversification of coconut water was reviewed by Thomas *et al.* (1987). The work done in India in this line is very little.

The coconut water could be used for making products like food yeast, vinegar, Nata-de-coco, carbonated and non-carbonated soft drinks and coconut water concentrates (Leufstedt, 1990; Gonzalez, 1993; Kaul, 1994 and Krishnankutty, 1996).

A technology for the enzymatic production of dextran and high fructose syrup from sugar supplemented coconut water has been developed (Lozano *et al.*, 1991).

Production of yeast and Nata-de-coco, from coconut is also reported by Markose (1994) and Aravindakshan (1996). Nata-de-coco is a gelatinous food product obtained from the action of a micro-organism (*Acetobacter xylinium*) on sugar reinforced coconut water or coconut milk mixed with glacial acetic acid.

Canning of tender coconut water with soft kernel pieces (6 x 2 cm) was attempted by Krishnankutty (1996).

Technology has been developed to manufacture wine from formulated coconut water using specially cultured wine yeasts. It had a distinct flavour and golden yellow colour. It contains an appreciable amount of A and B vitamins (APCC, 1996).

Coconut water can be utilised effectively as a natural floral preservative for lengthening the vase life of cut flowers. It is a low cost eco-friendly alternative to replace chemical preservatives (Attri *et al.*, 1999).

The effect of coconut water as a growth regulator on the growth of pepper cuttings was studied and found that dipping the cuttings in 25 per cent coconut water for 12 hours increased the number and length of roots and vigorous shoot growth (Yufdy and Ernawatt, 1987).

Fermented coconut water can be used a rubber coagulant (Thampan, 1993). Coconut water is added to cow dung to enhance the biogas production in gobar gas.

Coconut water can support the mycelial growth of edible mushrooms (Joson , 1989).

Coconut water is the cheapest medium for mass production of the fungus *Metarhizium anisopliae* a pathogen of several insect pests including *Oryctes rhinoceros* (Dangar, *et al.*, 1991).

2.10 STORAGE STUDIES IN COCONUT

Marar and Kunhiraman (1957) studied the keeping quality of ripe coconuts and concluded that if the period of storage was only short, no special precautions was necessary. If the period of storage was about a month, the nuts could be stored in the unhusked or partly husked condition. If the period of storage was longer (> 45 days), storing nuts in sand in the unhusked condition preferably in the vertical position with stalk-end up was found beneficial. Also, they observed that the period of storage could be enhanced by selecting well matured large sized nuts with oblong shape and in fresh condition.

Rajasekharan and Pandalai (1960) suggested that evolution of a method for storing tender coconut to prevent spoilage and retain the quality of freshness would help the tender coconut industry. They also hinted at the possibilities of use of cold storage to extend the life of tender coconuts.

Muliyar and Marar (1963) conducted storage studies of ripe coconuts. They used two shellac preparations "AL" and "DL" grades and paraffin to treat husked coconuts. Paraffin was found to be the best material. Even after 300 days only 35 per cent of the stored nuts were found dried up. They also observed that increasing the thickness of paraffin coating could increase the period of storage without driage. Muliyar and Markose (1974) reported that paraffin coated, dehusked ripe coconuts could be stored with water inside for a period of eight months. The kernel retained its freshness all through the storage period without any change in taste.

Ramanandan (1980) conducted a study to find out the length of storage of tender coconuts without water and kernel getting spoiled. The tender coconuts were stored in open, water, sand and buried in a pit of 45 x 60 cm covered with plated coconut leaves. He examined the acidity and taste of nut water at intervals of time and found that tender coconuts kept in sand remained good for 4-5 days and those kept in open for 3-4 days.

Reddy *et al.* (1981) conducted experiments on aqueous dipping of sodium hydroxide, sodium carbonate, sodium bicarbonate, sodium chloride, acetic acid and calcium propionate on cut halves of mature coconut. The change in colour, odour and taste of copra were estimated after drying. They observed that calcium propionate was better than glacial acetic acid. Brine was also found to be useful in the study.

Efforts were made to preserve coconut seed nuts in sealed packages by Saint *et al.* (1989). They opined that, it was possible, within certain limits, to delay coconut seed nut germination simply by packing them in sealed opaque bags. Storage in sealed bags made it possible to temporarily inhibit the germination process for up to four months in storage, without affecting the seed nut's germination capacity. In order to minimize the risk of germination during storage, it was recommended to harvest mature nuts when the epidermis was still coloured and not dried out.

Tongdee *et al.* (1991) recommended a dipping treatment for husked tender coconuts in 0.5 to one per cent sodium metabisulphite (SMS) for marketing within two days and two per cent SMS dipping for nuts to be held at ambient temperature for two to seven days. SMS dipping delayed the discolouration of the husked surface of the tender coconut.

2.11 STORAGE STUDIES IN OTHER CROPS

The mechanism by which seal packaging individual fruit in polyethylene film was investigated with lemon and bell pepper (Ben-Yehoshua *et al.*, 1983). Seal packaging effects were due to the water saturated atmosphere in the sealed enclosure around the fruit. Softening of fruit was highly correlated with declining water potential of fruits. The work supported hypothesis that mode of action of sealing in polyethylene related to the alleviation of water stress in the harvested fruit.

Roy and Pal (1993) reviewed the use of plastics in post harvest technology of fruits and vegetables. They opined that use of plastics in packaging of horticultural products help in minimizing cost of packaging materials and makes the whole process less dependent on scarce materials like wood, thereby resulting in conservation of environment.

Singh and Narayana (1995) studied the storage behaviour of 'Dashehari' mango in ventilated polybag and reported that packaging fruits in ventilated polybags extended their storage life and marketability and preserved quality better than control up to ten days.

Berry and Aked (1996) studied the causes of post harvest deterioration and loss in table grapes and concluded that modified atmosphere packaging delayed the post harvest senescence in grapes.

2.11.1 Effect of wax and other coatings on shelf-life

Dalal *et al.* (1970) studied the effect of wax coating on bananas of varying maturity and reported that only little difference was observed between waxed and untreated bananas (var. Dwarf Canvendish) with respect to ripening after harvesting. Under low temperature (14°C) eight per cent wax treated fruits remained green for 21 days. Durand *et al.* (1984) reported that waxing caused a slight build up of carbon dioxide and possible reduction in internal oxygen during pre-climacteric of stored 'Fuerte' avocado fruit. Further, they reported that waxing caused only one day delay in fruit softening under extended cold storage conditions.

Sankat and Maharaj (1993) reported that waxing appeared as a potential treatment for storage of mature green breadfruit with a potential to extend the marketable shelf-life to 18 days at 16°C. Use of edible coating for lightly processed fruits and vegetables were discussed by Baldwin *et al.* (1996). Fresh, minimally processed produce can be enrobed in edible materials, providing a semipermeable barrier to gas and water vapour. Such coatings reduced respiration and water loss, and can be used as carriers of preservatives and antioxidants. Edible coatings were generally made from lipids, resins, polysaccharides and proteins. Plasticisers such as polyhydric alcohols, waxes and oils were added to improve flexibility and elongation of polymeric substances.

Kabir *et al.* (1995) reported that Semperfresh (an edible coating) extended shelf-life of tomato cv. Pusa Early Dwarf by delaying ripening and decreasing the physiological weight loss. These edible coatings included hydrocolloids and substances isolated from waxes of fruits and vegetables.

2.12 LIGHT PROCESSING/MINIMAL PROCESSING IN COCONUT

Tongdee *et al.,* (1991) conducted some preliminary studies on light processing of coconuts. The rupture force at different maturity stages was measured and the use of SMS solution to prevent browning of trimmed nuts was assessed. Rupture force increased significantly as nut maturity advanced. The rupture force of commercially acceptable tender coconuts ranged between 97 and 182 kg. The nuts dipped for two minutes in 0.25, 0.5, 1.0, 2.0 or 4.0 (w/v) SMS solution, and then wrapped individually in polyethylene bags held at 22°C prevented browning for seven days. Brown irregular patches appeared on all treated nuts after seven days and were more intense on nuts dipped in four per cent SMS than lower concentrations of SMS. Concentration of 0.5 to 2.0 per cent SMS was recommended for nuts to be held at ambient temperature for 2-7 days.

Jiang *et al.* (1995) studied the effects of polyphenol oxidase (PPO) and peroxidase (POD) on the phenolic content of coconut fruits during processing and storage. PPO was able to oxidize monophenols, diphenols and polyphenols. The main phenols present in the coconut peels (epicarp and part of the mesocarp) were chlorogenic acid and dopamine. After a ten minute soak in boiling water followed by treatment with iced water containing one per cent sodium sulphite plus 0.02 per cent citric acid, there was significant inhibition of PPO and POD activities and significant reduction in phenolic content coincident with a milky white colour and good fruit quality when stored for 40 days at ten degree Celsius.

Raju (1998) observed the following in connection with the light processing of tender coconut. By trimming the husk there was mean weight reduction of 67.3 per cent. Reduction in volume was 69.3 per cent in COD, 74.69 per cent in D x T, 79.6 per cent in WCT and 82.71 per cent in T x D with a mean reduction in volume of 76.6 per cent. Dipping in chemical solutions of potassium metabisulphite (KMS) (0.5 or 1.0%) or ascorbic acid 0.01 per cent was found to prevent browning of LP nuts during storage. Citric acid (0.5 or 1.0%) was found effective as an acidulant to reduce microbial infection of LP tender coconuts. Dipping in a solution of 0.5% KMS + 0.5% citric acid was found effective for refrigerated storage and 0.5 per cent KMS + 1.0 per cent citric acid was found effective for storage of LP nuts in ventilated room.

2.13 LIGHT PROCESSING IN OTHER CROPS

Cantwell (1992) reported that all lightly processed fruits and vegetables were perishable and demonstrated post harvest quality degradation over time under ambient storage and it was more perishable than unprocessed fresh produce.

Brecht (1995) discussed the physiology of lightly processed fruits and vegetables. The consequence of wounding like ethylene synthesis, membrane lipid degradation, elevated respiration, oxidative browning, wound healing, secondary metabolites and water loss were examined. Species and variety, physiological maturity, severity of wounding, temperature, water vapour pressure deficit and atmospheric composition were listed as the variables affecting tissue response to wounding. As tools for marketing lightly processed fruits and vegetables, Schlimme (1995) listed temperature control, retarding moisture loss, altering composition of the atmosphere around the product, packaging and product microbiology.

Cameron *et al.* (1995) studied the film permeability requirements for modified atmosphere packaging of lightly processed fruits and vegetables. They opined that better control of oxygen level is necessary for control of fermentation and off-flavour development. For better control of oxygen levels, fundamental knowledge of the respiratory behaviour of the commodity was necessary.

Aspects of sanitation linked to shelf-life and safety of lightly processed fruits and vegetables were examined by Hurst (1995). He highlighted the role of processing, employee practices and plant sanitation as important areas of watch for maintaining safety standards during light processing.

2.14 MICROBIAL STUDIES ON COCONUT FRUITS

Fernandez (1988) conducted detailed studies for the presence of micro-organisms on mature coconuts with green and dried, brown husks during dry and rainy seasons. Samples for microbial examination were taken on the day of harvest, and after one and two weeks of storage. Examination of the interior tissues, namely, the liquid endosperm, the solid endosperm, the embryo and the haustorium of the nuts showed the absence of micro-organisms. The suspicion that the interior tissues of mature coconuts harboured *Salmonella* was also ruled out by this finding. The thin layers covering the basal pores (eyes) which are located external to the endocarp harboured some fungal species of *Thielaviopsis, Lephalopsporium, Licrosporium, Botrytis* and *Fusarium*. Fungi were absent on the thin layers of green husk nuts when sampled on the day of harvest. He concluded that no microbial isolates were obtained from the liquid endosperm whether it was from green or dried brown husked nuts, germinated or non-germinated nuts, and nuts sampled on the day of harvest or after one or two weeks of storage.

2.15 MARKETING TRENDS OF TENDER COCONUT

Rethinam (2001) has reported that tender coconut consumption in India has increased to 10 per cent of the total nut production.

Mathew (1991) undertook a study on the consumption of tender coconuts in Tamil Nadu. He estimated that the total consumption of tender coconuts in Tamil Nadu as 23.063 lakh nuts, which was 5.3 per cent of total coconut production in the state. His study indicated that the consumption of tender coconuts in Tamil Nadu was increasing. The demand for tender coconuts was high in summer months and the average price was Rs.2000 per thousand nuts. The total revenue added to the state's economy by way of sale of tender coconuts was worked out at Rs.24.45 crores. The trade of tender coconuts provided employment opportunities to agricultural labourers during off season.

Tender coconut is marketed in most of the towns and cities in India. In the country, Kolkata and Bangalore are the major markets for tender coconut. Mumbai is also an important market for tender coconut. College Street in Kolkata and Maddur in Karnataka are the major assembling markets for tender coconut in India. Tender coconut is widely marketed in the states of Tamil Nadu, Karnataka and Andhra Pradesh. Chennai and Madurai are the main consuming centres of the tender coconut in Tamil Nadu (Mathew, 1991). In West Bengal more than 80 per cent of the coconut produced is consumed in the form of tender coconut (Aravindakshan, 1996).

2.16 COMMERCIAL PLANTATION FOR TENDER COCONUT

Wazir (1997) reported that commercial coconut farms, for tender coconut purpose has already been established in many countries like Malaysia and Thailand. With the development of tender coconut industry in the country there is an urgent need to establish commercial farms from tender coconut production in major centres to make the tender coconut regularly at a cheaper rate.

Cultivation of dwarf type palms (COD, CGD) and their crosses with tall male parent are ideal. Planting them at a wider spacing of minimum 30' x 30' will be helpful in maintaining them short statured for easy harvest. Wider spacing also will help in introducing many suitable inter crops in the plantation.

2.17 BENEFITS OF HARVESTING TENDER COCONUT

Harvesting of tender coconuts is beneficial as about 25 per cent increase in yield is reported due to regular tender coconut harvest (Davis, 1962; Wazir, 1997). The problem of high arrivals of copra in the market in peak season also can be kept under check.

2.18 WASTE UTILISATION

The only thing that is not very sweet about the tender coconut is the problem of waste disposal. The vendors who sell the tender coconuts do not bother to collect and properly dispose off empty nuts (Davis, 1962).

The whole nut may be buried under the trees for manure. When the fresh husk was squeezed, the liquid that exuded contained a good amount of potash. The dried husk could be used for extracting the fibre and pith; though the quality of fibre was poor, it was a good raw material for making hard boards. The dry husk on burning yielded ash with a high potash content of 15 per cent (Davis, 1962). Ghosh (1978 a) reported that Mother Theresa had set up two mat production centres using tender coconut husk which was collected from streets by orphans and poor children.

2.18.1 Composting of tender coconut husk

Composting may be defined as a process of reducing the organic wastes converting the nutrients into ionic form which is available to the crops (Ramasamy 1995) by microbial action (bacteria and fungus) on the organic material. Rate of decomposition depends on whether the level of oxygen and microbial enzymes on the surface of the particles are adequate for aerobic metabolism of micro-organisms associated with the decomposition.

2.18.1.1 Factors affecting biomass decomposition

The decomposition of organic biomass is mainly the result of complex interactions between microbial populations and their activities which are controlled by the following factors.

2.18.1.2 Initial nitrogen content

Nitrogen content of the plant material has been shown to be an important factor controlling the rates of decomposition (Cowling and Merrill, 1966; Aber and Melillo, 1980). Several studies have demonstrated that the addition of supplementary nitrogen can enhance the rate of decomposition (Allison and Cover, 1960 and Mahendrappa, 1978).

2.18.1.3 C:N ration

C:N ratio in the plant residue also determines the rate of decomposition. Fog (1988) established that plant materials with high C:N ratio will not provide sufficient nitrogen for metabolism of microbe responsible for decomposition.

Jothimani (1993) reported that the lignin rich coir pith underwent high rate of mineralisation with the incorporation of *Pleurotus sajur caju* as indicated by a hike in the rate as well as cumulative Co_2 evolution in the soil and it was high when the coir pith was enriched with nitrogen in the form of urea. It also did not alter soil pH markedly .

Heat is generated while decomposing which may go up to 40 to 50°C and begin to drop when the decomposable organic matter depleted. Small particles have more surface area and will degrade more quickly.

When nitrogen content in the compost mix is very low decomposition rate will be very low. When the nitrogen content is very high the compost becomes too hot resulting the death of microbial population. It also may become anaerobic resulting in a foul smell. The recommended range of C/N ratio to start composting process is around 30/1. As carbon gets converted into CO_2 the C/N ratio decrease during decomposition and come close to 10/1. Pre-treatment of ligno-cellulosic material with ammonia or urea (Basaglia *et al.*, 1992), physical grinding (Fahry *et al.*, 1992) and Steam explosion (Sawada *et al.*, 1995) found to enhance the biodegradability of lignin.

Coir pith has been already recognised as an organic amendment and its potential in improving physical, chemical and biological characteristics of the soil is under various stages of experimentation. Various findings reported on the aspect is reviewed below.

2.18.1.4 Role of mineral nitrogen for organic matter break down

Nitrogen is a key nutrient substance for microbial growth and hence for organic matter breakdown. If the nitrogen content of the organic matter is poor decomposition is slow and carbon mineralisation will be stimulated by supplemented nitrogen (Allison and Cover, 1960; Mahendrappa, 1978 and Alexander, 1978).

Knapp *et al.* (1983) showed that straw decomposition rate was strongly dependent on available carbon and nitrogen during initial decomposition. When N was limiting, excess available carbon was apparently immobilised as poly-saccharides.

Fog (1988) summarised the various effects of added nitrogen on organic matter decomposition. According to him nitrogen added to decomposing organic matter has no effect or negative effect on microbial activity. A negative effect of nitrogen was in organic matter with a high C:N ratio but the reverse was true for easily degraded organic matter with low C:N ratio.

2.18.1.5 Effect of lignin on degradability

Lignin is difficult to biodegrade and reduces the biodegradability of other cell wall constituents (cellulose and hemi-cellulose). Lignin is a complex polymer of phenyl propane units, resistant to microbial degradation and it checks the bioavailability of other cell wall constitutes by checking the enzymatic penetration to them. Some organisms particularly fungi have developed the necessary enzymes to break lignin apart. Eg. white rot fungi (Kirk and Farrell, 1989). Actinomycetes can also decompose lignin but mostly less than 20 per cent of total lignin present (Basaglia *et al.* 1992). Lignin degradation is primarily an aerobic process and in anaerobic environment lignin can persist for long period.

2.18.1.6 Role of micro-organisms in degrading lignin in the organic waste

About 50.68 per cent of the lignin in the barley straw was removed by treating it with the culture filtrate of *P. sajor caju.* Holankoya (1987) reported that the *Pleurotus ostreatus* decomposed lignin and hemicellulose at higher rate than cellulose, only amorphus part of the cellulose seemed to be degraded. The degrading rate decreased in the following rate – lignin > hemicellulose > cellulose. Valmaseda *et al.* (1990) reported that *Pleurotus* sp. was the best among forty strains of fungi tested on decomposition of lignin.

Suitability of decomposed coir pith, as a manure for different crops was reported by several workers (Sharma and Mithra, 1990).

2.18.1.7 Role of microorganisms in combination with inorganics

Nagarajan *et al.* (1985) observed that after 26^{th} day of incubation with *Pleurotus* sp. and urea, the C:N ratio of coir pith was reduced. Coir pith inoculated with *Pleurotus* sp. plus inorganic fertilizers at 12.5 t ha^{-1} level registered higher yield of ground nut and rice (Nagarajan *et al.* 1986).

2.18.1.8 Method of decomposing

Ramasamy (1995) reported that delay in decomposition of coir pith was due to high content of lignin. He standardised a method for decomposing coir pith using the spawn of *Pleurotus sajor caju* and cow dung slurry which was effective to reduce the C/N ratio to 24:1 from 60:1 and enriched with available NPK. Low content of nitrogen in the plant residue also reported to delay the rate of decomposition (Bahuguna *et al.*, 1990). Ramasamy (1995) reported that delay in decomposition of coir pith was due to high content of lignin.

Bopaiah (1991) recommended one bottle spawn of *Pleurotus sajor caju* fungus and five kg of urea for decomposing one tonne of coir pith.

2.18.2 Silage

Silage is a forage conserved by anaerobic fermentation by the action of a lactic acid producing bacteria. Plant materials are chopped and compacted into a silo to exclude as much air as possible. The respiring plant cells use up the existing oxygen making the media favourable for anaerobic lactic acid producing microbes to proliferate. Fermentation continue, if sufficient quantity of soluble carbohydrates are present, until the accumulation of lactic acid depresses the pH to approximately four at which point further bacterial growth is inhibited and the silage is stabilised and well preserved until it is exposed to air (Peter , 1991).

2.18.2.1 Conventional forage used and their quality requirements for making silage

Forage such as grass, legumes, cereal fodder such as corn and sorghum are conventionally used for silage making. For production of good silage the forage must contain sufficient fermentable carbohydrate and when the content of carbohydrate is less some additives to supply soluble sugars are added. Molasses is commonly added as a source of alternative substrate for fermentation. The material to be ensiled should have a dry matter content of 30 to 35 per cent for optimum results. With low moisture content packing and thus exclusion of oxygen is difficult leading to heating and subsequently mould growth. With high level of moisture there will be putrefaction with Clostridia fermentation producing large amount of butrytic acid and offensive smelling amines such as tryptamine and histamine. Legumes have a high buffering capacity than grasses and require a high level of soluble carbohydrates to support sufficient fermentation to lower the pH adequately (Lassiter and Hardy, 1982; Peter, 1991).

2.18.2.2 Additives to silage

2.18.2.2.1 Fermentation promoters

a) Urea one per cent is added to silage material when it's protein content is low. It will also help adequate microbial development in rumen of the cattle (eg. corn silage).
b) Grains, tapioca flour, molasses, whey, citrus pulp, beet pulp etc. are added when the material is low in soluble carbohydrates. They also help to increase the dry matter content by absorbing excess moisture.
c) Anhydrous ammonia 0.8 to 0.9 per cent also added to supplement nitrogen content.

2.18.2.2.2 Fermentation inhibitors

Addition of acids was practiced to reduce the pH to 4 in order to inhibit fermentation. This is done to preserve carbohydrate because the fermentation will use up some amount of carbohydrate. Common organic acids used are, formic acid, acetic acid and propionic acid (Tilden *et al.*, 1999).

Products of microbial cultures and enzymes, when added to the silo, are reported to improve the quality of silage but only by considering cost factor (Lassiter and Hardy, 1982; Peter, 1991; Tilden *et al.*, 1999;).

2.18.2.3 Methods of silo making

Polythene covers of suitable size is reported to be the best container for compacting the material. For ensiling on experimental basis the compacted silo is made vacuum using a vacuum pump which is then covered with soil and kept as such for fermentation (Lassiter and Hardy, 1982; Peter , 1991; Tilden *et al.*, 1999).

2.18.2.4 Physiological changes in silos

It takes a minimum of 21 days to complete fermentation process. The grass in the silo continue to respire burning sugars, using up oxygen and giving out CO_2, water and heat.

$$C_6H_{12}O_6 + 6\ O_2 \rightarrow 6\ CO_2 + 6\ H_2O + 673\ \text{Cal.}$$

Once anaerobic condition is established bacteria in the silo starts to multiply. Acetic acid is produced first and pH comes to about 4.2. After three days acetic acid formation get slow down and lactic acid formation starts. Then slowly pH comes to 4. Temperature also comes down and bacterial action become arrested. Temperature in the silo should be about 30°C. When temperature is less butrytic acid is formed giving foul odour causing spoilage. At high temperature silage will have dark colour and tobacco like smell causing decrease in nutritive value due to loss of dry matter and crude protein (James, 1987).

With the proper amount of moisture, fermentable carbohydrate and proper storage the soluble carbohydrate fraction is almost entirely converted into organic acids and protein to amino acids (Lassiter and Hardy, 1982).

2.18.2.5 Desirable characters of silage

pH	- 4 -5.5
Colour	- Should not be black or burnt
Aroma	- Should have characteristic fruity aroma
Lactic acid	- 4.0 – 5.5
Acetic acid	- > 1.6%
Propionic acid	- > 0.22
Butrytic acid	- > 0.28
Fungal growth	- There should not be any usual symptom of fungal growth

2.18.2.6 Advantages of silage over fresh grass

1. Thick stemmed grass and other forage can be used
2. More palatable due to improved taste

3. Acidity in the silage is similar to the acids produced in the rumen. So quick digestion and absorption
4. Green fodder material can be made available in off season

2.18.2.7 Coconut waste in animal feed

Ananthasubramanian *et al.* (1982) conducted a feed trial with a conventional feed mixture replacing 10 per cent and 20 per cent with coir pith and found that there was no significant difference in the nutrient digestability and average weight gain in the experimental calves after a period of 184 days. This result indicates that incorporation of 20 per cent coir pith in cattle feed is feasible and economic.

Mathen *et al.* (1982) found that in two different feeding rations, one control and in another 30 per cent coconut pith, the digestibility coefficient of nutrients of both the rations were almost similar and all the animals maintained positive nitrogen balance.

In another trial with pepper waste in a coconut pith based ration also it was found to be beneficial and recommendable. In a 4 kg feed ration containing 1200 g of coir pith the total lignin consumed by the cattle can be worked out to be 360 g per day, the lignin content of coir pith being 30 per cent, which did not affect the digestibility (Mathen *et al.*, 1983).

Ananthasubramanian *et al.* (1983) reported that in a feeding trial with 25 per cent coir pith in the ration, the rate of growth in cross-bred calves was high though not significant over the control. Animals slaughted after the trial period of seven months did not have any pathological lesions in the internal organs. The digestibility coefficient of nutrients of the control and the experiment rations were not significantly different. The experimental group showed better gain of body weight. Cost per kg gain of body weight was also lower in experimental group; proving that coir pith @ 25 per cent appears to be feasible in economic calf rearing programme.

Lignin is an indigestible component in the plant cell wall which varies from 2-9 per cent in conventional forage fed to cattle. When the lignin content is very high it is likely to affect the digestion of cellulose and hemicellulose combined with lignin. But the above experiments show that incorporation of coir pith, which contains about 30 per cent lignin, even upto a level of 30 per cent in the ration is not affecting the digestibility coefficient of the nutrients and is contributing to body weight gain. In the light of the above result it is assumed that TCH, which contains only about 13.9 per cent lignin, can be an excellent feeding material if properly processed and ensiled.

2.18.3 Tender coconut husk as component of growing medium for Anthurium

Anthurium andreanum Lind is a flower crop of high value as an important cut flower. It is a tropical crop which thrives under high humidity. Anthurium cultivation in India is getting popularity. The present study was on the response of anthurium to different rooting media with tender coconut husk as one of the components.

2.18.3.1 Growing medium

The medium for growing in pit or bed should be light, well drained and rich in organic matter with easy availability. Leaf growth and flower production of anthurium were better in gravels in comparison to several growing media. Nakesone and Kamemoto (1962) found that 1:1 mixture of wood shavings and soil or 5:1 mixture of wood shaving and cow manure and tree fern fibre produced best plant growth.

Nikolava and Zafirova (1980) reported that a medium containing peat + pine bark + perlite (2:2:21) gave 98.9 per cent top grade flowers and 18 per cent higher flower yield as compared to other media used for growing anthurium. Voogt (1979) reported that the flower yield was inversely correlated with salinity of the soil. Out of the salts present in the soil sodium chloride was most detrimental to growth and flowering. According to Talukdar and Barooch (1987) *Dendrobium densiflorum* performed best in a combination of saw dust, charcoal, brick pieces and moss, followed by another medium containing coconut fibre and moss which showed superiority for growth characters, number of flowers per spikes and blooming period. Satisfactory results were obtained by replacing the coconut fibre with coconut husk pieces, or even by replacing charcoal with partially burnt husk pieces along with other components.

2.18.4 Tender coconut husk as component of substrate for mushroom culture

Mushroom is known for its high content of protein, essential amino acids, tryptophan, lysine and fibre content. It is a preferred choice for persons suffering from hyper acidity and constipation. It has got anticancerous properties and as starch and sugars are almost lacking, it is a good source of protein for diabetic patients (Jose and Janardhanan, 2000).

2.18.4.1 Media

Pleurotus spp. have been successfully cultivated in various agricultural waste such as paddy straw, coconut pith, coffee pulp (Bernabe *et al.*, 1993), Kidney bean and broad bean stubbles (Sobal *et al.*, 1993), sugarcane bagessee (Shi, 1994) and cotton waste (Haq *et al.*, 1994). Murugesan *et al.* (1995) reported the possibility of using water hyacinth for media for *Pleurotus* spp. Deka *et al.* (1994) reported that paddy straw was the best substrate for *P. sajor caju* and *P. florida*. Sangwan (1996) cultivated *P. sajor caju* on a mixture of sugar cane bagasse with paddy straw or wheat straw with a biological efficiency of 98.5 to 117.5 and 118.5 respectively.

2.18.4.2 Substrate preparation

When paddy straw is used as medium, the straw is cut into 4 cm pieces, immersed in water over night, steam sterilised and used for bed making. When coconut byproducts such as, bunch waste, leaves etc. are used, these materials are cut into 3-4 cm pieces with a chaff cutter either at half dry stage and dried well, or dry materials are immersed in water over night and then chopped. These materials after overnight soaking in water are taken out and steam sterilised before bed making (Namboodiri, 1999).

2.18.4.3 Sterilisation of the substrate

The substrate after overnight soaking and draining of the excess water is to be sterilised to make it free from microorganisms and to favour the growth of mushroom without any harmful effect. Sterilisation can be done either by steam or chemical method. Autoclaving is done at 1.02 kg cm^2 pressure for ½ hrs (or by keeping under boiling water for 1 hr). A local method of autoclaving using 200l petrol drums with lid and a netted false bottom at a 6" height from bottom. Coconut waste can be used as fuel for generating steam (Namboodiri, 1999).

In chemical method, the substrate filled in gunny bags is soaked over night in a solution of formalin 500 ppm (formaldehyde solution 37-41% w/v) + fungicide Bavistin 25 ppm (carbendazim). Approximately 100 litre solution with 5 g Bavistin and 125 ml formalin is required for 10 kg substrate. The sterilised material is taken out and allowed for draining excess water and used immediately for bed making (Namboodiri, 1999).

2.18.4.4 Bed making

Polythene bags of 45 x 35 cm size of 100-200 gauge are used with random holes of 0.5 cm size on it. The bottom of the cover is tied with a string to get a round bottom to the bed. Multi layered spawning technique is followed to inoculate the substrate with spawn @ 100 g/bag containing 3 kg substrate (Namboodiri, 1999).

2.18.4.5 Temperature requirement

Environmental factors like temperature aeration, humidity and light are most important in mushroom growing. Optimum temperature recorded is 25°C and optimum relative humidity is 86-90 per cent (Chadha, 1992).

2.18.4.6 *Supplementation to media*

Supplementation of substrate with various materials like horse gram powder, cotton seed powder, yeast mud, ground nut cake, rice bran @ 5 per cent can be added to improve the yield (Chadha, 1992; Namboodiri, 1999). Dhana *et al.* (1995) reported that supplementation of nitrogen as urea 1 to 1.5 per cent was beneficial in increasing the crude protein content of the mushroom.

2.18.4.7 *Crop management*

The beds will have to be kept for spawn running for 15 days which is then kept in growing racks in a specially made growing shed where the temperature and humidity are controlled by spraying water.

Mushroom production in different media

Species	Media	Mushroom yield (g/bed)	Biological efficiency (%)	Cropping period (days)	Reference
P. sajor caju	Coconut bunch waste	611.7	56.9	59.3	Namboodiri (1999)
	Coconut leaf stalk	709.5	58.9	72.6	
	Bunch waste/ leaf lets (1:1)	556.7	52.0	51.4	
	Coir pith + leaf stalk (1:1)	356.0	60.0	75.0	
P. florida	Paddy straw	700.0	87.5	-	Singh *et al.* (1995)
	Wheat straw	580.0	72.50	-	

2.18.4.8 *Biological efficiency (BE)*

Biological efficiency of the medium is worked as fresh weight of mushroom in g/100 g dry weight of the substrate. A high BE (60.0) is reported with coir pith + leaf stalk (1:1) media over the coconut bunch waste medias (Namboodiri, 1999).

Comparable performance of different *Pleurotus* spp.

Pleurotus spp.	Days for Spawn running	Days for 1st harvest	Yield (g/bed)	BE (%)	Colour
P. sajor caju	19	23	355	71	Gray
P. platypus	15	17	565	61	White
P. florida	14	17	305	61	White

2.18.4.9 Degradation of media

The extra cellular enzymes of *Pleurotus* spp. play a major role in the degradation of structural elements such as cellulose, hemicellulose, lignin and pectin present in the media. The enzymes associated with cellulose degradation are cellulases and those associated with lignin degradation are laccase (Wood, 1990).

2.18.4.9.1 Cellulase

Cellulose is a single polymer of β-1, 4 linked glucose units forms into insoluble microfibrils (Eriksson, 1978). The cellulase enzyme complex composed of three major enzymes viz. Endo β-1,4 glucanase (Cx) Exo β-1,4 glucanase (C_1) and β glucosidase. Extracellular enzymes like, cellulase, hemicellulase, amylase, pectinase and protease are also detected during the degradation of ligno-cellulosic medium.

Among various *Pleurotus* spp., *P. sajor caju* was reported to be the most efficient in producing cellulase (Hong *et al.*, 1985; Theradimani and Marimuthu, 1991).

2.18.4.9.2 Cellulose degradation

Sivaprakasam and Kandasamy (1981) reported that *P. sajor caju* during the growth period of 40 days utilised 15-25 per cent cellulose present in paddy straw. Dhana *et al.* (1996) reported reduction in cellulose content to 32.8 per cent and 25.85 per cent by *P. florida* and *P. sajor caju*, respectively in paddy straw after a growth period of 30 days.

Cellulose degradation in coir pith on inoculation with *P.* spp. has been reported as 53 per cent after 30 days by Nagarajan *et al.* (1985) and Theradimani and Marimuthu (1991).

2.18.4.9.3 Laccase

Saxena and Rai (1992) have reported significant activities of laccase during the growth of *P. sajor caju* on wheat straw, which is responsible for the degradation of legnin. Similar results have been reported by Reddy (1985).

2.18.4.9.4 Lignin degradation

Lignin is a very complex structure formed by the oxidative polymerisation of coumaril, coniferyl and synapyl alcohol (Krik and Farrell, 1989; Bhoominathan and Reddy, 1992). Lignin degradation is important in the global recycling of carbon because of the abundance of lignin in the biosphere and it delimit the degradation of cellulose and other poly saccharides (Kirk and Farell, 1989).

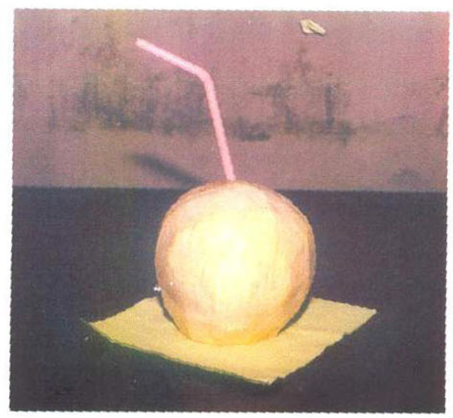
Lignin is one of the important factors which influences the physical constituent of soil through its ability to reduce and concentrate aromatic rings which, as they become humic acid, represent the very basis of soil structure (Lemieux, 1996).

All fungi capable of degrading lignin are known as white rot fungi. *Pleurotus* is a white rot fungi capable of degrading lignin (Zandrazil and Dube, 1992). Bisaria and Madan (1984) reported 97 per cent loss in lignin during the cultivation of *P. sajor caju* on paddy straw for 40 days. Nagarajan *et al.* (1985) reported reduction of lignin content to 4.8 per cent in coir pith with *Pleurotus* sp. from the initial 30 per cent in 30 days. Theradimani and Marimuthu (1991) reported 82 and 78 per cent reduction in lignin content of coir pith with *P. sajor caju* and *P. platypus* respectively.

2.18.5 Calorific value of L P tender coconut shell

Coconut crop residue is a major source of fuel material in village households wherever coconut is grown. Tender coconut waste thrown off after consuming the water is also collected by the rural poor for fuel purpose. LP tender coconut shell also can be utilised as a fuel material. Hence, estimation of calorific value of the tender coconut waste material was included in the technical programme. The calorific value of other traditional fuel wood materials is reported to be ranging from 3.8 to 4.1 kg cal g^{-1} Shanavas (2001).

Materials and Methods



3. MATERIALS AND METHODS

Investigations on the development of an integrated light (minimal) processing (LP) technology for tender coconut (TC) and tender coconut husk (TCH) based products were carried out at the College of Horticulture, Vellanikkara, Thrissur during 1999-2001.

Soil characters

College of Horticulture, Vellanikkara is situated at an altitude of 22.25 m above MSL, latitude of 10^{o} 32' N and longitude 76^{o}10'E. Details of soil characters of the experimental location are furnished in Appendix – 1.

Weather characters

The annual rainfall at Thrissur during 2001 received in 106 rainy days was 2400.9 mm. Meteorological data recorded during 2001 are presented in Appendix – 2.

Experimental Details

Altogether six experiments were carried out under this programme, details of which are furnished below.

3.1 EXPERIMENT - I

Standardisation of packaging and storage requirements for lightly processed (LP) tender coconut in selected cultivars.

3.1.1 Materials

3.1.1.1 Selection of varieties

The following varieties and hybrids were selected for this study.

West Coast Tall (WCT)

Chavakkad Orange Dwarf (COD)

COD x Tall

Tall x GB

The palms available in the Instructional Farm, College of Horticulture, Vellanikkara and DSP Farm, Coconut Development Board, Vellanikkara were utilised for this study.

Coconut bunches were tagged on the day of splitting of the spathe, to facilitate harvest at desired maturity. Harvesting of bunches were done at a maturity level of seven months (Davis, 1962 and Chinnaraj,1997), approximately between 210-215 days. Bunches were lowered from palms with the help of a coir rope and transported carefully to the laboratory for further studies.

3.1.2 Methods

Light processing (minimal processing) technology standardised by Raju (1988) detailed below was followed and the nuts of four varieties were subjected to the treatments under different storage environments.

3.1.2.1 Trimming of husk

Husk of the TC was trimmed off manually with a sharp knife retaining about 0.5 cm of husk around the nut.

3.1.2.2 Dipping trimmed TC in KMS + citric acid solution

Five litres of 0.5 per cent KMS and 0.5 per cent citric acid solution was prepared in a plastic bucket for dipping the trimmed TC. The trimmed TC was dipped in this solution for three minutes taking care to keep the nut fully immersed in the solution by keeping a suitable weight over the nut.

3.1.2.3 Packaging of the above LP nut in LDPP covers

Low density polypropylene covers of 0.025 mm thickness and size (20 cm x 25 cm) was used. Forty ventilation holes of 4 mm diameter were made in the cover randomly distributed covering up to 15 cm surface of the cover. LP nuts taken out from the dipping solution were allowed to drain off the excess moisture and packed in the cover. The open end of the cover was closed by tying with a rubber band. In the second method of packaging cling film (Vardhman-II, R.S. Hygiene Pvt. Ltd., Rajouri Garden, New Delhi 2) was used for tight packaging (Plate 2).

3.1.2.4 Treatments

T_1 - LP tender coconut packed in LDPP (0.025mm) cover with ventilation holes and stored in open room condition

T_2 - LP tender coconut packed in LDPP (0.025mm) cover with ventilation holes and stored in refrigerator (5-7°C). Top loading cooler was used for this purpose.

T_3 - LP tender coconut wrapped in cling film and stored in open room condition.

T_4 - LP tender coconut wrapped in cling film and stored in top loading cooler at 5-7°C (Plate 1).

T_5 - Whole tender coconut kept in open ground.

T_6 - Whole tender coconut kept in room condition.

Design of experiment: CRD

No. of replication : 4

3.1.3 Observations

Observations were recorded at an interval of two days starting from the day of harvest and continued till the samples turned unacceptable.

3.1.3.1 Biometric characters

a) Weight of nut

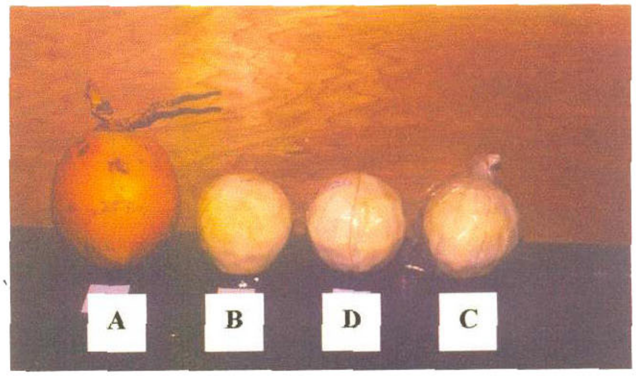
The weight of whole nut and the LP nut was recorded in grams. Loss of weight by trimming operation was recorded as percentage.

b) Length of nut

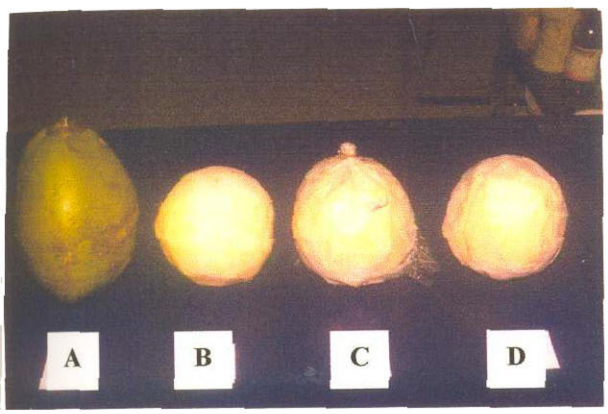
The length of whole nut and the LP nut was taken and recorded in cm. Reduction in length due to minimal processing also was recorded and expressed in percentage.

Plate 1. Top loading cooler used for chilling minimally processed tender coconut

WCT



COD



T x GB

COD x T

A - Whole nut; B - LP nut; C - LP nut with ventilation packing;
D - LP nut with cling film rapping

Plate 2. Whole nuts and LP nuts of selected varieties

c) Breadth of nut

The breadth of whole nut and the LP nut was taken and recorded in cm. Reduction in breadth due to minimal processing also was recorded and expressed in percentage.

d) Volume of nut

The volume of the whole nut and the LP nut was observed and recorded in millilitre by water displacement method. The reduction in volume due to minimal processing also was recorded and expressed in percentage.

e) Volume of tender coconut water (TCW)

One eye of the TC was opened with the help of a special screw tip tool and all the tender coconut water was transferred to a measuring cylinder and the volume was expressed as millilitre.

f) Weight of TCW

The weight of TCW is taken in an open pan balance and expressed in gram.

g) Specific gravity of TCW

Specific gravity of TCW was worked by using a specific gravity bottle and electronic monopan balance.

h) Weight of husk

The weight of total husk, husk trimmed and husk retained with LP nut were observed and recorded in gram. Then the percentage of total husk and the percentage of husk removed were observed and recorded.

i) Weight of kernel

Kernel portion of the TC was carefully scooped out and the weight was expressed in gram.

j) Weight of shell

The weight of TC shell after removing the kernel and the outer layer of husk, was taken and recorded in gram. The percentage share of husk, shell, kernel and TCW in a whole nut was worked out. The above observations were taken for ten nuts and mean recorded.

k) Physiological loss of weight (PLW)

Physiological loss of weight was recorded on every alternate days and recorded as percentage in each treatment.

$$\text{PLW (\%)} = \frac{\text{Initial weight} - \text{weight after storage}}{\text{Initial weight}} \times 100$$

3.1.3.2 Biochemical characters

a) Total soluble solids (TSS)

Total soluble solids (TSS) of TCW was determined using a hand refractometer (Erma Tokyo, 0-32%, Made In Japan) and result expressed in degree brix.

b) Acidity

Titrable acidity of TCW was estimated as per AOAC (1990) method and expressed in percentage.

c) pH

The pH of TCW was recorded using a digital pH meter (Model No.Ph 5652 A Electronic Corporation of India Ltd.).

d) TSS – Acidity ratio

TSS-acidity ratio was worked out from the TSS, acidity values in respective cases.

e) Estimation of total, reducing and non-reducing sugars

Total and reducing sugars were estimated by the AOAC (1990) method and expressed in percentage. Non-reducing sugar was estimated by subtracting reducing sugar from the total sugar.

f) Sensory evaluation

The sensory evaluation for assessing the appearance taste and aroma of TCW before and after storage was done by a panel of five judges using a five point Hedonic scale as proposed by Ranganna (1986).

Score points for taste and aroma

Very good	: 5
Good	: 4
Satisfactory	: 3
Not acceptable	: 2
Dislike very much	: 1

g) Storage life

The period up to which the TC remained acceptable under each treatment according to its external and internal quality parameters was observed and recorded in number of days. Development of one of the following defects was considered critical to determine the total storage life.

- Discolouration and/or disfiguration of external surface
- Development of off-flavour/taste (Mean score below three)
- Cloudiness of the TCW

3.2 EXPERIMENT - II

Development of technologies for utilisation of fresh tender coconut husk.

3.2.1 Experiment - IIA - Composting of fresh tender coconut husk

3.2.1.1 Materials

Fresh tender coconut husk was prepared for the experiment by cutting it into approximately one cm size bits.

3.2.1.2 Treatments

T_1 - Composting of the fresh tender coconut husk with cow dung (10%) and kept in room condition.

T_2 - Composting of fresh tender coconut husk with urea 5% and *Pleurotus sajor caju* culture (2%)and kept in room condition.

T_3 - Composting of fresh tender coconut husk alone and kept in room condition.

T_4 - Composting of fresh tender coconut husk with cow dung (10%) and buried in soil.

T_5 - Composting of fresh tender coconut husk with urea (5%) and *Pleurotus sajor caju culture* (2%) and buried in soil.

T_6 - Composting of fresh tender coconut husk alone and buried in soil.

Under treatments T_1 to T_3 the materials were kept in room conditions for incubation in LDPE (0.025mm) covers of 30 x 40 cm size with random ventilation holes. Five kg of husk was put in the cover sandwitching with the other components in five layers.

Under treatments T_4 to T_6 materials were buried in soil after packing in nylon nets under shaded condition –Mesh-bag technique (Bocock and Gilbert, 1957). Samples in all six cases were watered regularly to keep the material moist always.

Design of experiments : CRD

No. of replications : 4

3.2.1.3 Observations

Observations were recorded for the content of N, P, K, Ca, Mg and S of the samples at monthly intervals using standard procedures followed for analysis (Bhargawa and Raghupathy, 1993).

Total carbon: Total carbon content was found out by igniting the samples at 550°C.

Nitrogen: Total nitrogen was estimated by Kjeldhals method .A sample of 0.1 g digested in 10 ml of conc. H_2SO_4 using digestion mixture (sodium sulphate, copper sulphate in 10:4 ratio).

Phosphorus: A known weight (1 g) sample digested in diacid mixture (Nitric acid, perchloric acid 3:1 ratio). Digest was made upto 100 ml. A known aliquot was taken to determine the phosphorus content by following chlorostanus reduced molybdophosphoric blue colour method in sulphuric acid system and the colour intensity was read at 660 nm in UV spectrophotometer.

Potassium: A known volume of aliquot of diacid extract was taken to determine potassium content using Flame photometer.

Calcium: One ml of the diacid extract was mixed with one ml of stronortium chloride solution (1000 ppm) volume was made up to 25 ml. Calcium content in the sample was read using atomic absorption spectrophotometer.

Magnesium: One ml of stronortium chloride was added to 0.1 ml of the diacid extract and made up to 25 ml and the magnesium content was determined by atomic absorption spectrophotometer.

Sulphur: Sulphur content was estimated by turbidometry using $BaCl_2$. The turbidity was read at 400 nm in UV spectrophotometer.

Lignin: Lignin content was estimated by following the procedure suggested by Van Soest and Wine (1968). One g powdered sample was refluxed with acid detergent solution and the content was filtered and washed with hot water and acetone. The left over residue was dried in an oven at 100°C for over night and the weight was taken after cooling in a desiccator. The weighed material was mixed with 50 ml of 72 per cent H_2SO_4 and added with one g of asbestos powder and allowed to remain for three hours with intermitant stirring. The content was diluted and filtered with pre-weighed Whatman No.1 filter paper and washed repeatedly to remove acid component. The residue in the filter paper was dried, weighed and subjected to ashing in a muffle furnace at 550°C for 5 hours. The contents were cooled in a desiccater. The ash was weighed and lignin, content was calculated.

3.2.2 Experiment - IIB - Ensiling of tender coconut husk

3.2.2.1 Preparation of tender coconut husk

Tender coconut husk (TCH) was firstly cut longitudinally with two cm width. Then the outer green thin layer (exocarp) of the husk was peeled off. The husk was then cut cross wise in 0.5 cm thickness which was then spread over a clean floor for one day for adjusting the excess moisture to 65-70 per cent from the original moisture level of 81-83%.

3.2.2.2 Treatments

Moisture adjusted TCH was thoroughly mixed with different ingredients as per the following treatments.

T_1 - TCH mixed with fresh tapioca flour (5%)

T_2 - TCH mixed with pineapple waste (25%)

Pineapple waste (outer peel) collected from fruit processing unit was spread over a clean floor for one day for moisture adjustment to 65-70 per cent from the original 90-95 per cent moisture.

T_3 - TCH mixed with molasses (8%)

Molasses collected from the Dairy Farm, College of Veterinary and Animal Sciences, Mannuthy was utilised for this purpose. T.C.H. was moisture adjusted to 60-62 per cent in this case.

T_4 - T.C.H. mixed with 5 per cent jaggery

T_5 - T.C.H. alone

3.2.2.3 Vacuum packaging and storage

Five kg sample of TCH mixed with respective additive was packed compact in polythene cover of 200 gauge and then the air inside the pack was removed with the help of a vacuum pump (Toshniwal High Vaccum Pump, cat No.CL 71-100, Tovac Equipments, Madras-58).

These packets were then kept in plastic buckets of suitable size and the packets were covered with soil from all sides. Soil was put upto the brim of the bucket. Silage samples were taken out after six weeks of incubation and fed to cattle.

Design of experiment : CRD

Replications : 6

3.2.2.4 Observations

a) pH of silage (acqueous extract) using pH meter.

b) Odour of the silage (fruity and fermented/foul odour) by sensory method.

c) Fungal growth by visual method.

d) Acceptability to cattle

Silage samples were fed to six dry cows and the quantity consumed was recorded. Trial feeding was given in initial two days and observations taken from 3^{rd} day onwards, for all the five samples for six days continuously.

e) Chemical composition of tender coconut husk (on dry weight basis)

Crude protein, crude fat, crude fibre, nitrogen free extract, total ash, N, P, K, Ca, Mg and S content of TCH was tested (AOAC, 1990).

Neutral detergent fibre, acid detergent fibre and acid detergent lignin were also determined (Van Soest, 1963; Van Soest and Wine, 1968; AOAC, 1990).

f) Calorific value

Calorific value of silage samples were found out by Bomb calorimeter method, (No.128978 Advance Research Institute Co., New Delhi) (ARICI, 1995).

3.2.3 Experiment - IIC - Utilisation of TCH as a component in growing medium for anthurium

The experiment was laid out to assess the suitability of utilisation of tender coconut husk (TCH) as a component of growing medium for anthurium in pots.

3.2.3.1 Materials

A popular hybrid variety, 'Hawaiian Red' of *Anthurium andreanum* (Lind.) having good demand for cut flowers was used for the study. Plants maintained in the Floriculture Nursery, Dept. of Pomology and Floriculture, College of Horticulture, were used. Age of the plants at planting was about 4½ months.

3.2.3.2 Medium

Different combinations of the following materials such as coarse sand, rotten cowdung, matured coconut husk, tender coconut husk, charcoal and pieces of clay roofing tiles at a ratio of 2:1:2:2:0.5:2 were used. The ingredients were arranged in layers.

Salvi (1997) reported that matured coconut husk can be well utilised as one of the components of growing medium for anthurium with a combination of sand rotten cow dung, mature coconut husk, wood shavings, charcoal, earthen crocks, bricks pieces in a ratio of 2:1:2:1:0.5:0.5:1. Tender coconut husk also having very good water holding capacity was, therefore, tried as a substitute for mature coconut husk.

Both tender and matured husk pieces were prepared by cutting them into pieces of 2-3 cm size and drying them under sun.

3.2.3.3 Treatments

T_1 - Bits of clay roofing tiles, matured coconut husk, tender coconut husk in 2:2:2 ratio + standard potting mixture (sand, cow dung in 2:1 ratio) 2 portions.

T_2 - Bits of clay roofing tiles and tender coconut husk in 2:2 ratio + standard potting mixture 2 portions.

T_3 - Charcoal and tender coconut husk in 2:2 ratio + standard potting mixture 2 portions.

T_4 - Bits of clay roofing tiles and mature coconut husk in 2:2 ratio + standard potting mixture 2 portions.

T_5 - Standard potting mixture alone.

T_6 - Standard potting mixture and tender coconut husk in 2:2 ratio.

3.2.3.4 Crop management

To boost up the growth the anthurium plants were sprayed with "Greencare" (30:10:10 NPK with micro nutrient) at 0.05 per cent concentration, and with a complex fertilizer (17:17:17 NPK) 0.5 per cent were given in alternate weeks. Irrigation was given by over head sprinkler. Supernatant solution of neem cake (1:10) prepared by soaking cake in water for four days was sprayed once in a month.

3.2.3.5 Re-potting

Re-potting was done at five month stages. Few pieces of clay roofing tiles were placed above the hole in the pot, above which coarse sand were put. It was followed by other components in layers each of 3-4 cm around the plant. Above that a filler mixture of sand and cow dung was spread over it to fill the gaps. Thereafter a thin layer of filler mixture of sand and cowdung was given at monthly intervals. Irrigation was followed in summer month and hot spells in rainy season by sprinkler method. Drainage was cared for. Weeding was done as and when required. Neem cake solution (1:10) was sprayed during and after the rainy season.

The crop was grown under green house with 75 per cent shade. The observations were recorded for a period of ten months when the first flowering phase was over.

Experiment design: CRD
Replication: 4

3.2.3.6 Observations

The following observations were recorded at monthly intervals.

a) Plant height

Plant height was measured in cm from the base to the tip of the tallest leaf.

b) Plant spread

Spread of the plant N/S and E/W directions were recorded in cm at monthly intervals.

c) Leaf number

Total number of leaves at monthly intervals were noted.

d) Leaf area and leaf area index

The leaf length from base of lobe to the tip and width at the centre of the index leaf were measured in centimetre. The product of this values was multiplied by a factor 0.72 and then by total number of leaves to get the total leaf area (Salvi, 1997).

The leaf area index was worked out by dividing the total leaf area by spread area of each plant.

e) Petiole length

The length of the petiole of 2^{nd} leaf from base was recorded in cm from the base of the petiole to the base of the leaf blade.

f) Number of days taken for flowering

Number of days taken for flowering was counted from the date of first potting.

g) Length of flower stalk (Peduncle)

Length of flower stalk from its point of emergence to the point of attachment of the spathe was measured in cm.

h) Length and breadth of spathe

The length of the spathe from the joint of peduncle to the tip and breadth at the centre were measured and expressed in cm.

i) Spadix length

Length of spadix from the base to tip was measured and expressed in cm.

j) Number of flowers per plant

Total number of flowers produced by each plant during the experimental period of ten months was recorded.

3.2.4 Experiment - IID - Utilisation of TCH as medium for mushroom cultivation

Possibilities of using TCH as medium for growing edible sp. of mushroom *Pleurotus sajor caju* and *P. florida* was investigated. The experiment was carried out at IRTC Mundur, Palakkad.

3.2.4.1 Materials

Spawns of the *Pleurotes* spp. collected from IRTC, Mundur, Palakkad, Kerala were utilised.

3.2.4.2 Preparation of media components

T.C.H. trimmed off while preparing L.P. nut was used. T.C.H. was chopped into small pieces and dried well under sun. Paddy straw was cut into 5 cm long pieces. Media are given over night dipping in water and then steam sterilised.

3.2.4.3 Sterilisation of media

Instead of chemical method of sterilisation, steam sterilisation was followed. This was helpful in reducing the water content of the medium. T.C.H. was holding moisture of about 3-4 times of its weight after chemical sterilisation, which is not suitable for spawn running.

The TCH after overnight dipping in water was taken up and kept for sometime till the water was fully drained. Then it was steam sterilised for one hour. Steam sterilisation was done in a copper vessel, keeping the material over a wire net kept above 10 cm from the bottom of the vessel in which water was taken only upto 3-4 cm level. While steam sterilisation the moisture from the TCH was drained and collected in the boiling vessel. It helped to bring down the moisture of TCH to desired level at cooling over the wire net. Paddy straw was also steam sterilised for half an hour.

3.2.4.4 Treatments

T_1 – TCH + *P. sajor caju* culture 12.5%.

T_2 – TCH + *P. florida* culture 12.5%.

T_3 – Conventional method with paddy straw + *P. sajor caju* culture 12.5%.

T_4 – Conventional method with paddy straw + *P. florida* culture 12.5%.

3.2.4.5 Preparation of mushroom bed

The media (of 1 kg dry weight) was filled in polythene bags of 30 cm x 60 cm size with ventilation holes made at 3 cm space. For every 5 cm depth of media 25 g of spawn and other components were filled in the bags in alternate layers. The open end of bags were tied with a rubber band and kept for spawn running (for about 15 days) till the initiation of the fruiting body (mushroom) was visible. These beds were taken to growing shed and kept in specially made stands in a hanging form. Humidity in the shed was maintained between 70-85 per cent RH by spraying water over the clean sand spread over the floor. The mushroom beds were also sprayed with water on alternate days to keep them sufficiently wet till the end of the crop period. Harvesting was done as and when the mushroom was ready for harvest.

Design of experiment : CRD

No. of replications : 4

3.2.4.6 Observations

a) Days taken for spawn running

b) Days taken for first harvest

c) Total yield (g per bed)

d) Crop period (from bed-making to last harvest)

e) Colour at harvest (sensory evaluation)

f) Taste of mushroom (sensory evaluation) Ranganna (1986).

g) Biological efficiency of the medium

$$B.E. = \frac{\text{Total wt. of the produce in g}}{\text{Total wt. of the dry substrate in g}} \times 100$$

3.2.5 Experiment - IIE - Calorific value of minimally processed tender coconut shell

3.2.5.1 Materials

Shell of the minimally processed tender coconut shell which can be used as fuel material was used.

3.2.5.2 Methods

Tender coconut shell was dried and finely powdered and it's calorific value was determined by bomb calorimeter method.

3.3 EXPERIMENT III – PILOT TESTING OF THE LIGHT (MINIMAL) PROCESSING TECHNOLOGY

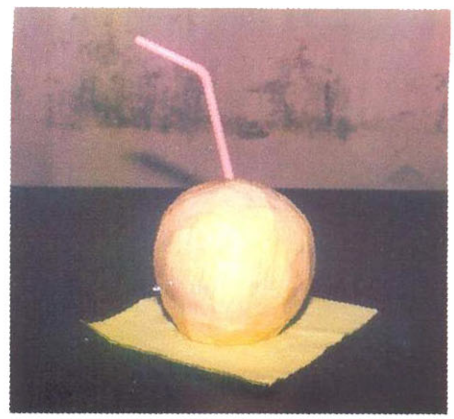
3.3.1 Pilot testing of the lightly (minimally) processed tender coconut (Treatment-T_2)

L.P. nut under treatment – T_2 (L.P. nut packed in 0.25 mm LDPP cover with 40 ventilation holes and refrigerated at 5-7°C) were served to the consumers. The observations were collected from the consumers by way of response sheet, every alternate days of storage (up to 20^{th} day) till the samples turned unacceptable. It was conducted at Agricultural Technology Information Centre (ATIC), Mannuthy under KAU.

3.4 STATISTICAL METHODS

The data recorded were subjected to statistical scrutiny by analysis of variance (Panse and Sukhatme, 1985). Whenever the treatments differed significantly, they were compared by DMRT (Duncan's Multiple Range Test) (Federer, 1955).

Results



4. RESULTS

Experimental results

Investigations on minimal processing of tender coconut comprising trimming of husk, chemical treatments, packaging and low temperature storage were carried out to standardise a suitable method to improve the storage life of TC which will help to make the tender coconut a ready to serve (RTS) chilled natural beverage. Utilisation of tender coconut husk for various purposes viz. composting, silage making, and as growing medium for anthurium and mushroom were also undertaken with a view to generate a viable method for the disposal of the tender coconut husk which is a non-eco-friendly bulky waste. The results obtained from various experiments are presented in this chapter.

4.1 PRELIMINARY OBSERVATIONS

4.1.1 Biometric characters of the tender coconut

The following biometric characters of the four selected varieties were observed and the data are presented in Table 1.

4.1.1.1 Weight of the whole tender coconut

Among the four cultivars WCT gave the heaviest tender coconut (2486 g). It was followed by the tender coconut from hybrids T x GB and COD x T (2156 g and 1555 g respectively) which were statistically on par. The smallest nut was produced by COD (1145 g).

4.1.1.2 Weight of the minimally processed nut

Weight of the minimally processed nut also showed the same pattern ranging from 1099 g in WCT to 845 g in COD. In T x GB and COD x T it was 928 g and 878 g respectively and all the three varieties, except WCT, were statistically on par.

4.1.1.3 Reduction in weight due to minimal processing

Percentage of reduction in nut weight due to light (minimal) processing was minimum in COD (41.4%) and in the other three varieties it ranged from 55 to 56 per cent and they were on par.

Table 1. Biometric characters of TC in selected cultivars and hybrids

Cultivars	Weight of whole nut (g)	Weight of LP nut (g)	Reduction in weight (%)	Vol. whole nut (ml)	Vol. LP nut (ml)	Reduction Vol. (%)	Length of whole nut (cm)	Length of LP nut (cm)	Reduction in length (%)	Breadth whole nut (cm)	Breadth LP nut (cm)	Reduction in breadth (%)
WCT	2486.67^{a}	1099.17^{a}	55.54^{a}	2655.00^{a}	1094.17^{a}	58.28^{a}	20.92^{a}	10.45^{c}	50.03^{a}	16.33^{a}	11.65^{a}	28.47^{a}
COD	1145.00^{c}	845.00^{b}	41.45^{b}	1500.00^{d}	828.33^{c}	44.75^{b}	17.58^{b}	11.83^{ab}	31.70^{c}	14.50^{b}	11.17^{a}	22.94^{b}
T x GB	2156.67^{b}	928.33^{b}	56.78^{a}	2283.33^{b}	947.50^{b}	57.80^{a}	20.17^{a}	12.08^{a}	39.58^{b}	13.83^{b}	11.25^{a}	18.52^{b}
COD x T	1999.00^{b}	878.33^{b}	55.03^{a}	2073.33^{b}	798.33^{c}	61.30^{a}	17.83^{b}	11.33^{b}	36.12^{bc}	14.67^{b}	11.67^{a}	20.23^{b}
Mean	2020.83	937.71	52.20	2127.97	917.08	55.30	19.13	11.43	39.39	14.83	11.43	22.54

Means with different superscripts are significantly different (P=0.05)

Table 1. contd.

Cultivars	Weight of husk (g)	% of husk	Weight of shell (g)	% of shell	Weight of kernel (g)	% of kernel	Weight of TCW (g)	% of TCW	Volume of TCW (ml)	Specific gravity	Weight of husk in LP nut (g)	% of husk trimmed off
WCT	1796.67^{a}	71.75^{a}	150.83^{a}	6.13^{b}	158.33^{a}	6.58^{b}	380.83^{a}	15.53^{b}	360.83^{a}	1.05	409.17^{a}	77.57^{b}
COD	818.33^{c}	56.55^{c}	143.33^{a}	9.90^{a}	132.50^{b}	9.17^{a}	348.33^{a}	24.38^{a}	304.17^{a}	1.01	218.33^{b}	74.28^{b}
T x GB	1503.33^{b}	69.55^{ab}	155.83^{a}	7.23^{ab}	149.17^{ab}	7.03^{b}	308.33^{a}	16.22^{b}	339.17^{a}	1.00	275.00^{b}	81.95^{a}
COD x T	1333.33^{b}	66.67^{b}	147.50^{a}	7.42^{ab}	145.00^{ab}	7.28^{b}	369.17^{a}	18.63^{b}	360.83^{a}	1.02	216.67^{b}	83.65^{a}
Mean	1362.92	66.13	149.37	7.67	146.25	7.52	362.29	18.69	341.25	1.02	279.79	79.36

Means with different superscripts are significantly different (P=0.05)

Table 2. Biochemical characters of the TC in selected cultivars and hybrids

Cultivar	Acidity (%)	pH	TSS (°Brix)	TSS/Acidity	TS (%)	RS (%)	NRS (%)	Taste (score)
WCT	0.128^{a}	4.78^{b}	4.87^{b}	46.23^{b}	4.75^{b}	3.98^{a}	0.77^{a}	4.58
COD	0.109^{a}	5.10^{a}	5.10^{a}	51.67^{ab}	5.15^{a}	4.22^{a}	0.93^{a}	4.92
T x GB	0.118^{a}	5.17^{a}	4.43^{c}	52.32^{a}	4.37^{c}	3.43^{b}	0.95^{a}	4.67
COD x T	0.107^{a}	4.71^{b}	4.07^{d}	47.35^{b}	3.74^{d}	3.30^{b}	0.44^{b}	4.80
Mean	0.116	4.94	4.62	48.10	4.50	3.73	0.77	4.74

Means with different superscript are significantly different (P = 0.05)

4.1.1.4 Volume of whole nut

Volume of the nut was significantly higher in WCT (2655 ml) and it was significantly low in COD (1500 ml). In T x GB and COD x T it were 2283.3 ml and 2073.3 ml respectively and they were on par statistically.

4.1.1.5 Volume of light (minimally) processed nut

Highest volume of LP nut was recorded in WCT (1094.2 ml) which was significantly different from other cultivars. Lowest volume of LP nut was in COD x T (798.3 ml) which was on par with COD (828.3 ml). In T x GB volume was very close to WCT.

4.1.1.6 Reduction in volume due to light (minimal) processing

Percentage reduction in volume due to trimming of husk was on par in all three varieties (61.3%), except COD. In COD reduction in volume was significantly low (44.6 %).

4.1.1.7 Length of whole tender coconut

There was no significant variation in length of whole nut in WCT and T x GB (20.9 cm and 20.17 cm respectively) but they were superior to COD and COD x T which were also on par (17.58 cm and 17.83 cm respectively).

4.1.1.8 Length of light (minimally) processed nut

Length of LP nut was ranging from 10.45 cm to 12.08 cm. the highest being in T x GB and the lowest in WCT. In COD and COD x T the length of LP nut was on par (11.8 cm. and 11.3 cm respectively).

4.1.1.9 Reduction in length due to light (minimal) processing

Reduction in length was significantly higher in WCT (50.03%). In COD it was minimum (31.7%), and other hybrids, T x GB and COD x T (39.6 and 36.1 respectively) were on par in respect of this character.

4.1.1.10 Breadth of whole tender coconut

Breadth of whole tender coconut was significantly high in WCT (16.3 cm.). It was followed by T x GB, COD and COD x T (13.8 cm., 14.5 cm., 14.6 cm. respectively) and they were on par.

4.1.1.11 Breadth of light (minimally) processed tender coconut

Breadth of LP nut was statistically similar in all cultivars. It was 11.17 cm in COD, 11.25 cm in T x GB, 11.67 cm in COD x T and 11.65 in WCT.

4.1.1.12 Reduction in breadth due to light (minimal) processjng

Reduction in breadth of nut due to trimming was significantly high in WCT (28.4%). In other cultivars it was on par, the lowest being in T x GB (18.5 %).COD recorded 22.9 % and COD x T recorded 20.2% reduction in breadth.

4.1.1.13 Share of husk

Weight of husk was significantly high in WCT (1796 g). It was significantly low in COD (818 g). T x GB and COD x T were on par (1503 g and 1333 g respectively) with respect to the weight of husk (Fig.1).

Of the total nut weight, percentage share of the husk was 71.75 in WCT followed by T x GB (69.55), COD x T (66.67) and COD (56.55).

4.1.1.14 Share of shell

There was no significant variation among the cultivars in respect of weight of the shell. It was 143.33g in COD, 147.50g in COD x T, 150.83g in WCT and 155.83g in T x GB.

Regarding the share of the shell in total nut weight it was significantly high in COD (9.9%). Other cultivars were on par with 6.13% in WCT,7.23% in T x GB and 7.42% in COD x T.

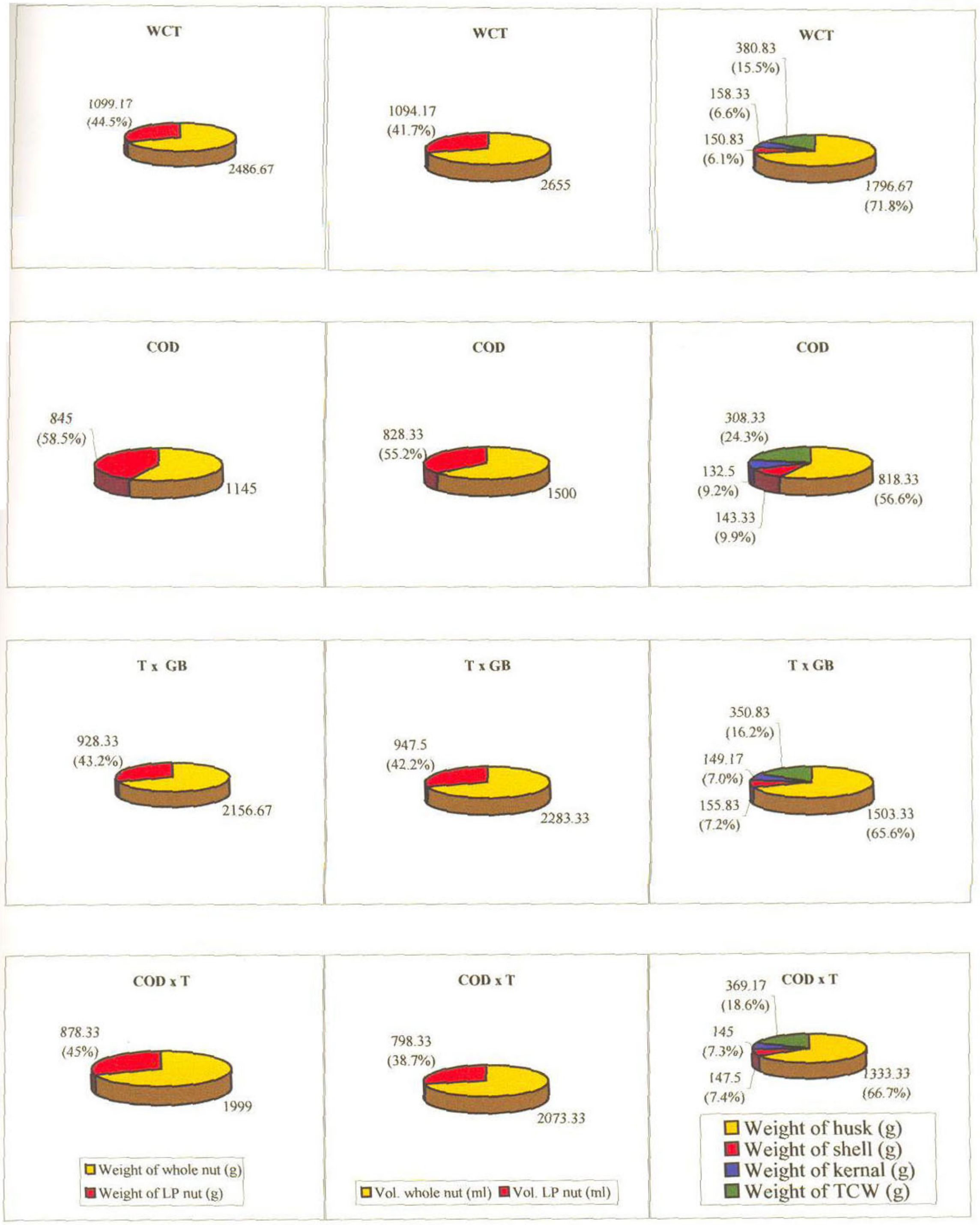


Fig. 1. Biometric characters of tender coconut in selected cultivars and hybrids

4.1.1.15 Share of kernel

Weight of kernel was significantly higher in WCT (158.33 g) which was followed by T x GB (149.17 g), COD x T (145.0 g) and the lowest in COD (132.5 g).

The percentage contribution of kernel to the total nut weight was significantly high in COD (9.17) and in others it was on par (7.28 g in COD x T, 7.03 g in T x GB and 6.58 g in WCT).

4.1.1.16 Share of tender coconut water (TCW)

Among the cultivars weight of TCW was ranging from 380.83 g in WCT, 369.17 g in COD x T, 350.83 g in COD and 348.33 g in T x GB and all were statistically on par.

Regarding their percentage share on total nut weight, COD had significantly high share(24.38%). All the other three cultivars were on par with each other having 18.63 per cent in COD x T, 16.22 per cent in T x GB and 15.53 per cent in WCT.

4.1.1.17 Volume of tender coconut water (TCW)

Volume of tender coconut water among the cultivars studied had significant difference. The highest value was 360.83 ml in WCT and also in COD x T. It was followed by COD (339.17 ml) and T x GB (304.17 ml).

4.1.1.18 Specific gravity of tender coconut water (TCW)

Specific gravity was ranging from 1.00 to 1.05 with no significant difference among the cultivars.

4.1.1.19 Weight of husk retained in light (minimally) processed nut

Weight of husk retained with LP nut (after trimming) was significantly high in WCT (409.17 g). It was followed by T x GB (275.00g), COD (218.33g) and COD x T (216.67g).

4.1.1.20 Percentage of husk trimmed

Percentage of husk removed out of the total husk was significantly high in COD x T (83.65%) and T x GB (81.95%) to WCT (77.57%) and COD (74.28%).There was no significant difference between COD x T and T x GB.

4.1.2 Biochemical characters of tender coconut water (TCW)

Biochemical characters of tender coconut water were analysed and the result are given in Table 2.

4.1.2.1 Acidity (%) of tender coconut water (TCW)

Acidity of the TCW had no significant difference between the cultivars. The highest value was recorded in WCT (0.128%) followed by T x GB (0.12%), COD (0.11%) and COD x T (0.11%).

4.1.2.2 pH of the tender coconut water (TCW)

There was no significant difference in pH of the TCW among two cultivars viz. COD (5.10) and T x GB (5.17). But they were significantly higher than WCT (4.78) and COD x T (4.71), which were also on par.

4.1.2.3 Total soluble solids (TSS° Brix) in tender coconut water (TCW)

Cultivars were distinctly different with respect to their TSS content in the order of COD (5.10° Brix), WCT (4.87° Brix), T x GB (4.43° Brix) and COD x T (4.07° Brix).

4.1.2.4 TSS/Acidity ratio of tender coconut water (TCW)

Cultivar T x GB had a significantly higher ratio (52.32) which was on par with COD (51.67). There was no significant difference between WCT (46.23) and COD x T (42.18).

4.1.2.5 Total sugars (%) in tender coconut water (TCW)

Cultivars had statistically different levels of total sugars in the order of 5.15% in COD, 4.75% in WCT, 4.37% in T x GB and 3.74% in COD x T.

4.1.2.6 Reducing sugars (%) in tender coconut water (TCW)

As far as reducing sugars was concerned the cultivars were in two significantly different groups. COD (4.22%) and WCT (3.98%) in higher group and T x GB (3.43%) and COD x T (3.28%) in lower group.

4.1.2.7 Non-reducing sugars (%) in tender coconut water (TCW)

Non-reducing sugars was significantly low in COD x T (0.44%). The other three cultivars were on par recoding 0.95% in T x GB, 0.93% in COD and 0.77% in WCT.

4.1.2.8 Taste of tender coconut water (TCW)

Taste was assessed by organoleptic scoring method. It was not statistically analysed. As per the mean values of scoring maximum value (out of 5) was scored by COD (4.92) followed by COD x T (4.80), T x GB (4.67) and WCT (4.58).

4.2 EXPERIMENT I. EFFECT OF MINIMAL PROCESSING AND STORAGE METHODS ON THE STORAGE LIFE AND QUALITY OF THE TENDER COCONUTS OF SELECTED CULTIVARS

4.2.1 Storage life of tender coconut

There was an appreciable period of storage life for minimally processed tender coconut under refrigerated condition. Among the treatments under refrigeration, ventilated packing gave longer period of storage life (Table 3).

Under T_2 (ventilated packing + cold storage) it was up to 18^{th} day. Under T_4 (cling film wrapping + cold storage) it was up to 10^{th} day only (Plate 3-5).

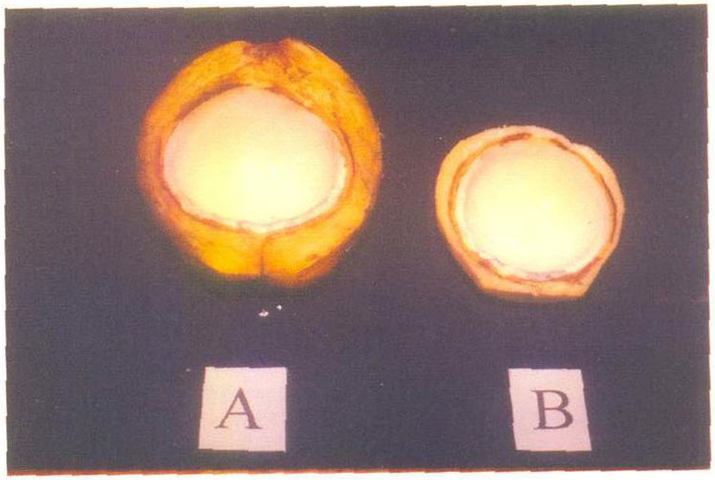


Plate 3. Cross section of whole nut and LP nut

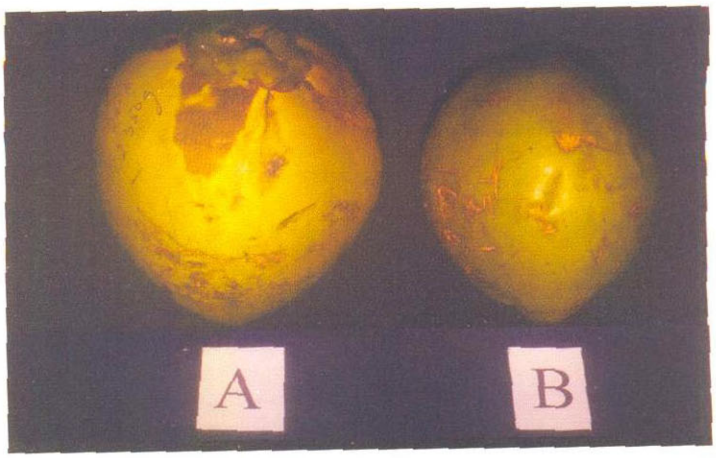


Plate 4. Damage under open and room condition storage

Plate 5. LP nuts untreated and treated with KMS + Citric acid solution

Table 3. Storage life and nature of damage of tender coconut under different treatments

Treatments	Storage life (days)	Nature of damage
LP nut under room condition T_1 T_3	 6 days 6 days	Development of an off-flavour and slight cloudiness to the TCW
LP nut under refrigerated condition T_2 T_4	 18 days 10 days	Development of an off-flavour to the TCW
Whole nut under Open condition - T_5	6 days	Development of an acidic taste to TCW
Room condition – T_6	8 days	Development of slightly acidic taste to TCW

Minimally processed nuts under T_1 and T_3 (LP tender coconut with ventilated packaging and cling film packing respectively) stored under room condition and whole nuts stored in open condition (T_5) were not acceptable beyond sixth day in all cultivars. The whole nut stored in room condition (T_6) kept good up to eighth day of storage in all the cultivars studied.

The nature of damage noticed in general was the development of an off flavour to the TCW.

4.2.2 Causes for consumer unacceptability

The reason for unacceptance, in general was the development of an undesirable flavour in TCW for all treatments and cultivars. LP nut with cling film wrapping was more prone to it than those packed in ventilated packaging in LDPP covers.

4.2.3 Quality parameters

4.2.3.1 Effect of light (minimal) processing and storage methods on physical loss of weight (PLW%)

The trend in PLW between the treatments was same in all the varieties on second day of storage (Table 4). During the storage period same pattern was noticed

Table 4. Effect of light (minimal) processing and storage methods on physiological loss of weight (PLW %) of tender coconut

Treat-ments	PLW (%) 2nd day					PLW (%) 4th day					PLW (%) 6th day				
	WCT	COD	T x GB	COD xT	Mean	WCT	COD	T x GB	COD xT	Mean	WCT	COD	TxGB	CODxT	Mean
T_1	3.59^{a}	0.70^{abc}	1.12^{c}	1.53^{b}	1.74^{bc}	5.33^{a}	1.14^{b}	3.40^{a}	3.27^{c}	3.29^{b}	6.47^{b}	2.93^{bc}	5.16^{c}	3.67^{c}	4.56^{c}
T_2	0.00^{d}	0.00^{c}	0.00^{d}	0.00^{d}	0.00^{d}	0.03^{c}	0.00^{c}	0.00^{c}	0.00^{d}	0.01^{c}	0.00^{c}	0.22^{d}	0.00^{d}	0.33^{d}	0.14^{d}
T_3	2.35^{b}	0.63^{c}	2.17^{b}	2.17^{b}	1.83^{b}	2.19^{b}	1.48^{b}	2.69^{ab}	3.27^{c}	2.41^{b}	4.85^{b}	2.41^{c}	3.79^{c}	4.67^{c}	3.94^{c}
T_4	0.07^{d}	0.00^{c}	0.00^{d}	0.00^{d}	0.02^{d}	0.07^{c}	0.00^{c}	0.00^{c}	0.00^{d}	0.02^{b}	0.05^{c}	0.17^{d}	0.00^{d}	0.00^{d}	0.06^{d}
T_5	3.69^{a}	1.40^{a}	3.97^{a}	3.33^{a}	3.09^{a}	5.62^{a}	5.09^{a}	5.65^{c}	7.67^{a}	6.18^{a}	15.7^{a}	20.07^{a}	14.27^{a}	15.33^{a}	16.34^{a}
T_6	1.63^{c}	1.13^{b}	0.83^{c}	0.83^{c}	1.11^{c}	2.27^{b}	1.35^{b}	1.95^{b}	2.80^{c}	2.09^{b}	5.33^{b}	4.13^{b}	7.73^{b}	6.00^{b}	5.80^{b}
Mean	1.89	0.64	1.35	1.31	1.29	2.59	1.51	2.28	2.83	2.33	5.40	4.99	5.16	5.00	5.04

Table 4. contd.

Treatments	PLW (%) 8th day					PLW (%) 10th day					PLW (%) 12th day				
	WCT	COD	TxGB	CODxT	Mean	WCT	COD	TxGB	CODxT	Mean	WCT	COD	TxGB	CODxT	Mean
T_1	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
T_2	0.00^{b}	0.10^{b}	0.05^{b}	0.93^{b}	0.27^{b}	0.07	0.20	0.10	1.33	0.43	0.07	0.33	0.13	0.83	0.34
T_3	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
T_4	0.07^{b}	0.17^{b}	0.08^{b}	0.00^{b}	0.08^{b}	0.10	0.07	0.13	0.71	0.25	0.17	0.13	0.13	1.17	0.40
T_5	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
T_6	9.00^{a}	6.32^{a}	8.30^{a}	10.53^{a}	8.54^{a}	D	D	D	D	D	D	D	D	D	D
Mean	3.02	2.16	2.81	3.82	2.96	D	D	D	D	D	D	D	D	D	D

Table 4. contd.

Treatments	PLW (%) 14th day					PLW (%) 16th day					PLW (%) 18th day				
	WCT	COD	TxGB	CODxT	Mean	WCT	COD	TxGB	CODxT	Mean	WCT	COD	TxGB	CODxT	Mean
T_1	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
T_2	0.10	0.47	0.40	1.00	0.49	0.17	0.67	0.54	1.20	0.64	0.25	0.93	0.55	1.40	0.78
T_3	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
T_4	0.19	D	D	D	D	D	D	D	D	D	D	D	D	D	D
T_5	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
T_6	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
Mean	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D

Means with the same superscript are not significantly different ($P = 0.05$); D- Damaged up to sixth day. Maximum cumulative weight loss was recorded in un-refrigerated storages of which T_5 gave significantly higher mean value (16.34%) followed by T_6 (8.54%) on eighth day. Samples under refrigerated storage T_2 (LP tender coconut + ventilated packaging + cool storage) and T_4 (LP tender coconut + cling film wrapping + cold storage) showed very negligible level of PLW throughout the storage period and on 12th day it was 0.34% 0.40% respectively. For T_2 it was 0.5% on 16th day. The treatments T_1 (LP tender coconut + ventilated packaging) and T_3 (LP tender coconut + cling film wrapping) both under room condition, were on par (4.56% and 3.94% respectively) on sixth day.

On eighth day T_6 (whole nut under room condition) showed a mean value of 8.54 per cent PLW and T_2 and T_4 were on par with 0.27 and 0.08 per cent of PLW respectively. On subsequent days minimally processed nuts under refrigerated condition could keep well up to 18th day in T_2 and upto 10th day in T_4 with a PLW level of 0.78% and 0.25% respectively.

In the case of T_5 (the whole nut stored under open condition) the PLW was steadily increasing from 3.69% on second day to 15.70% on sixth day when it was turned unacceptable in the case of WCT. The same trend was noticed in other varieties also with the PLW level of 20.07% in COD, 14.27% in P x GB and 15.33% in COD x T and all were turned unacceptable on sixth day of storage.

With respect to T_6 (the whole nut stored in room condition) the cumulative PLW was 9.00% in WCT, 6.32% in COD, 8.30% in T x GB and 10.53% in COD x T at the end of the storage life on eighth day.

4.2.3.2 *Effect of light (minimal) processing and storage methods on the total soluble solids (TSS °Brix) of the tender coconut water (TCW)*

There was no significant difference between treatments in any of the varieties in their TSS values on second day of storage (Table 5).

During the storage there was a slight decrease in TSS values over the period in all varieties under all treatments. General response of the varieties to the

Table 5. Effect of light (minimal) processing and storage methods on total soluble solids (TSS °Brix) of tender coconut water (TCW)

Treatments	TSS (°Brix) 2nd day					TSS (°Brix) 4th day					TSS (°Brix) 6th day				
	WCT	COD	TxGB	CODxT	Mean	WCT	COD	TxGB	CODxT	Mean	WCT	COD	TxGB	CODxT	Mean
T_1	4.80[a]	4.93[a]	4.73[a]	5.10[a]	4.89[a]	4.80[b]	4.97[ab]	4.58[a]	4.53[b]	4.82[b]	4.43[b]	4.67[b]	4.23[ab]	4.93[a]	4.57[ab]
T_2	5.00[a]	5.10[a]	4.43[a]	5.17[a]	4.92[a]	5.00[a]	5.07[a]	4.26[a]	5.13[a]	4.84	4.87[a]	4.43[b]	3.99[ab]	4.97[a]	4.56[ab]
T_3	4.93[a]	5.00[a]	4.43[a]	5.10[a]	4.87[a]	5.20[ab]	4.87[b]	4.25[a]	5.07[a]	4.80[b]	4.80[a]	4.50[b]	4.23[ab]	4.97[a]	4.63[ab]
T_4	4.97[a]	5.23[a]	4.33[a]	5.10[a]	4.91[a]	4.83[b]	5.23[a]	4.33[a]	4.90[ab]	4.85[b]	4.60[ab]	5.17[a]	4.20[ab]	4.90[a]	4.72[a]
T_5	4.67[a]	5.17[a]	4.33[a]	4.90[a]	4.79[a]	5.00[b]	5.17[ab]	4.37[a]	4.83[ab]	4.84[b]	4.30[b]	4.67[b]	4.30[ab]	4.90[a]	4.54[b]
T_6	4.93[a]	4.93[a]	4.53[a]	5.13[a]	4.88[a]	5.43[a]	5.18[b]	4.40[a]	5.07[a]	4.91[a]	4.87[a]	4.63[b]	4.37[a]	4.90[a]	4.69[ab]
Mean	4.88	5.06	4.48	5.08	5.00	5.12	5.05	4.37	4.99	4.85	4.64	4.68	4.22	4.93	4.62

Table 5. contd.

Treatments	TSS (°Brix) 8th day					TSS (°Brix) 10th day					TSS (°Brix) 12th day				
	WCT	COD	TxGB	CODxT	Mean	WCT	COD	TxGB	CODxT	Mean	WCT	COD	TxGB	CODxT	Mean
T_1	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
T_2	4.53[a]	4.20[b]	4.30	4.83[a]	4.47[a]	4.53	4.13	4.07	4.83	4.39	4.50	4.13	3.97	4.73	4.33
T_3	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
T_4	4.33[a]	4.63[a]	4.17[ab]	4.83[a]	4.49[a]	4.43	4.43	4.03	4.80	4.40	4.60	4.27	4.02	4.70	4.40
T_5	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
T_6	4.60[a]	4.17[b]	3.93[b]	4.83[a]	4.38[a]	D	D	D	D	D	D	D	D	D	D
Mean	4.49	4.33	4.13	4.83	4.45	4.48	4.23	4.05	4.82	4.40	4.55	4.20	3.99	4.72	4.36

Table 5. contd.

Treatments	TSS (°Brix) 14th day					TSS (°Brix) 16th day					TSS (°Brix) 18th day				
	WCT	COD	TxGB	CODxT	Mean	WCT	COD	TxGB	CODxT	Mean	WCT	COD	TxGB	CODxT	Mean
T_1	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
T_2	4.33	4.27	3.93	4.67	4.30	4.33	4.00	3.83	4.00	4.04	4.07	3.83	3.80	3.80	3.88
T_3	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
T_4	4.20	D	D	D	D	D	D	D	D	D	D	D	D	D	D
T_5	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
T_6	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
Mean	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D

Means with the same superscript are not significantly different (P = 0.05); D - Damaged

treatments was more or less uniform during the storage period. Fall in TSS value at 18th day was from 5.00 to 4.07 in WCT and from 5.10 to 3.83 in COD, from 4.43 to 3.8 in T x GB and from 5.17 to 3.80 in COD x T under T_2. During the storage there was a slight decrease in TSS values over the period in all varieties under all treatments. Under T_4 though the storage life was not extended beyond 12th day it recorded same mean value of 4.40.

On eighth day of storage only T_2 (ventilation packaging + cool storage), T_4 (Cling film wrapping + cool storage) and T_6 (whole nut under room condition) were in acceptable condition and they were statistically on par in their TSS values in WCT (4.53,4.33 and 4.60 °Brix respectively) and in COD x T (4.83 °Brix in all the three treatments). In COD T_2 and T_6 were similar and inferior to T_4. In T x GB T_6 was inferior.

After sixth day data were not statistically analysed due to the lack of sufficient number of treatments due to the termination of storage life in T_1, T_3, T_5 and T_6 and in these cases rate of decrease in TSS was faster which was from 4.89 to 4.57 in T_1, 4.87 to 4.63 in T_3, 4.79 to 4.54 in T5 and 4.88 to 4.69 in T_6. Only T_2 (ventilation packaging + cold storage) and T_4 (cling film wrapping + cold storage) remained good and their mean values of TSS in each variety was showing more or less same trend at each stages, though it showed a decreasing trend. At the end of storage life of 18th day T_2 showed a decrease from 5.00 to 3.88 and in T_4 from 4.97 to 4.40.

4.2.3.3 Effect of light (minimal) processing and storage methods on the acidity (%) of the tender coconut water (TCW)

There was no significant difference in acidity of the TCW between treatments in any of the varieties due to minimal processing and storage (Table 6). However, the acidity of the TCW stored under refrigerated condition recorded low value than in other treatments. On sixth day highest value of acidity was noticed in treatment 5 (whole nut stored in open condition) 0.134 (%) followed by T_6 (0.130%), T_1 (0.125%) and T_3 (0.123%) in WCT. The trend was similar in COD x T. In other varieties, COD and T x GB the acidity level was ranging from 0.09 to 0.1 having no

Table 6. Effect of light (minimal) processing and storage methods on acidity (%) of tender coconut water (TCW)

Treat-ments	Acidity (%) 2nd day					Acidity (%) 4th day					Acidity(%) 6th day				
	WCT	COD	TxGB	CODxT	Mean	WCT	COD	TxGB	CODxT	Mean	WCT	COD	TxGB	CODxT	Mean
T_1	0.125[a]	0.107[a]	0.110[a]	0.120[a]	0.115[a]	0.125[a]	0.100[a]	0.109[a]	0.118[a]	0.113[a]	0.125[a]	0.101[a]	0.106[a]	0.120[a]	0.113[a]
T_2	0.121[a]	0.107[a]	0.110[a]	0.121[a]	0.114[a]	0.118[a]	0.109[a]	0.103[a]	0.119[a]	0.112[a]	0.122[a]	0.095[a]	0.108[a]	0.119[a]	0.111[a]
T_3	0.116[a]	0.110[a]	0.113[a]	0.123[a]	0.115[a]	0.120[a]	0.093[a]	0.103[a]	0.120[a]	0.109[a]	0.123[a]	0.100[a]	0.102[a]	0.118[a]	0.111[a]
T_4	0.117[a]	0.110[a]	0.113[a]	0.126[a]	0.116[a]	0.120[a]	0.097[a]	0.113[a]	0.122[a]	0.113[a]	0.124[a]	0.093[a]	0.109[a]	0.117[a]	0.109[a]
T_5	0.128[a]	0.116[a]	0.113[a]	0.126[a]	0.121[a]	0.129[a]	0.094[a]	0.109[a]	0.124[a]	0.109[a]	0.134[a]	0.093[a]	0.106[a]	0.129[a]	0.116[a]
T_6	0.125[a]	0.110[a]	0.113[a]	0.123[a]	0.118[a]	0.124[a]	0.097[a]	0.109[a]	0.124[a]	0.114[a]	0.130[a]	0.090[a]	0.111[a]	0.121[a]	0.113[a]
Mean	0.122	0.110	0.112	0.123	0.117	0.121	0.098	0.108	0.121	0.112[a]	0.126	0.095	0.107	0.121	0.112

Table 6. contd.

Treatments	Acidity (%) 8th day					Acidity (%) 10th day					Acidity (%) 12th day				
	WCT	COD	TxGB	CODxT	Mean	WCT	COD	TxGB	CODxT	Mean	WCT	COD	TxGB	CODxT	Mean
T_1	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
T_2	0.126[a]	0.106[a]	0.103[a]	0.116[a]	0.113	0.122	0.099	0.095	0.116	0.108	0.120	0.098	0.095	0.116	0.107
T_3	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
T_4	0.129[a]	0.093[a]	0.105[a]	0.121[a]	0.107	0.115	0.093	0.084	0.116	0.102	0.113	0.093	0.083	0.114	0.101
T_5	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
T_6	0.133[a]	0.083[a]	0.097[a]	0.118[a]	0.107	D	D	D	D	D	D	D	D	D	D
Mean	0.129	0.094	0.101	0.118	0.109	D	D	D	D	D	D	D	D	D	D

Table 6. contd.

Treatments	Acidity (%) 14th day					Acidity (%) 16th day					Acidity (%) 18th day				
	WCT	COD	TxGB	CODxT	Mean	WCT	COD	TxGB	CODxT	Mean	WCT	COD	TxGB	CODxT	Mean
T_1	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
T_2	0.124	0.098	0.093	0.115	0.108	0.123	0.093	0.090	0.116	0.110	0.112	0.100	0.120	0.120	0.113
T_3	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
T_4	0.120	D	D	D	D	D	D	D	D	D	D	D	D	D	D
T_5	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
T_6	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
Mean	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D

Means with the same superscript are not significantly different (P = 0.05); D - Damaged

significant difference. Between T_2 and T_4 also there was no significant difference in acidity till 12th day of storage life (0.107% and 0.101% respectively). On 18th day the mean value of acidity was 0.113% in T_2 which was 0.104% initially.

4.2.3.4 *Effect of light (minimal) processing and storage methods on the TSS/acidity ratio of the tender coconut water (TCW)*

The ratio between the TSS and acidity is an important factor in deciding the taste and acceptability of TCW. The data in Table 7 show that the highest value of TSS/acidity was recorded by COD (46.51) followed by COD x T (41.29), T x GB (40.15) and WCT (40.15). There was no significant difference in TSS/acidity ratio up to fourth day of storage in WCT. On sixth day T_6, T_1 and T_5 were showing significantly low values (37.32, 36.02 and 32.83 respectively) in WCT. In COD it showed a fluctuating trend. Among T x GB and COD x T there was no significant difference between the treatments. In general variety COD was showing high value of TSS/acidity ratio followed by COD x T, T x GB and WCT throughout storage period.

On eighth day also there was no significant difference between the existing treatments of T_2 (ventilated packaging + cool storage), T_4 (cling film wrapping + cool storage) and T_6 (whole nut stored in room condition). Subsequently on 18th day treatment T_2 remained acceptable with TSS/acidity value of 34.01 (WCT), 36.1 (COD), 40.75 (T x GB) and 40.15 in (COD x T) showing a gradual reduction from the initial values. It was found to come down from 42.39 to 42.33 under T_4 on 12th day.

As in the case of other quality parameters there was a slight fall in the TSS/acidity ratio also in all the varieties, over the storage periods.

4.2.3.5 *Effect of light (minimal) processing and storage methods on the pH of the tender coconut water (TCW)*

Data on pH did not show any statistical difference between treatments under any variety on second day of storage (Table 8). There after T_3 (cling film wrapping + stored in room condition) showed significantly low value of 4.56 only in WCT but, highest value was noticed in COD in T_3 and T_5 (both 5.07). On sixth day all

Table 7. Effect of light (minimal) processing and storage methods on TSS/Acidity ratio of tender coconut water (TCW)

Treat-ments	TSS/Acidity 2nd day					TSS/Acidity 4th day					TSS/Acidity 6th day				
	WCT	COD	TxGB	CODxT	Mean	WCT	COD	TxGB	CODxT	Mean	WCT	COD	TxGB	CODxT	Mean
T_1	38.43^{a}	46.48^{a}	43.01^{a}	42.49^{a}	42.60^{a}	38.36^{a}	49.96^{b}	42.16^{a}	42.28^{a}	43.19^{a}	36.02^{bc}	46.40^{cd}	40.04^{a}	40.38^{a}	40.71^{a}
T_2	41.43^{a}	48.24^{a}	40.43^{a}	42.73^{a}	43.21^{a}	42.41^{a}	48.96^{b}	41.21^{a}	41.64^{a}	43.56^{a}	41.02^{a}	4690^{cd}	37.07^{a}	41.63^{a}	41.66^{a}
T_3	42.64^{a}	45.68^{a}	39.22^{a}	41.70^{a}	42.31^{a}	40.67^{a}	53.20^{ab}	41.23^{a}	42.23^{a}	44.33^{a}	41.21^{a}	45.94^{c}	41.05^{a}	42.63^{a}	42.38^{a}
T_4	42.46^{a}	48.14^{a}	38.51^{a}	40.46^{a}	42.39^{a}	40.20^{a}	54.33^{ab}	38.34^{a}	40.23^{a}	43.29^{a}	40.24^{ab}	56.49^{ab}	38.41^{a}	40.84^{a}	44.00^{a}
T_5	36.39^{a}	44.51^{a}	39.41^{a}	38.70^{a}	39.75^{a}	43.46^{a}	55.55^{a}	40.06^{a}	38.93^{a}	44.50^{a}	32.83^{c}	50.90^{bc}	40.78^{a}	39.73^{a}	41.06^{a}
T_6	39.52^{a}	48.98^{a}	40.35^{a}	41.67	41.88^{a}	41.13^{a}	51.02^{ab}	40.58^{a}	40.78^{a}	43.38^{a}	37.32^{abc}	52.96^{ab}	41.90^{a}	41.21^{a}	43.35^{a}
Mean	40.15	46.51	40.15	41.29	42.02	41.04	52.17	40.59	41.02	43.71	38.11	49.93	39.96	41.07	42.27

Table 7. contd.

Treatments	TSS/Acidity 8th day					TSS/Acidity 10th day					TSS/Acidity 12th day				
	WCT	COD	TxGB	CODxT	Mean	WCT	COD	TxGB	CODxT	Mean	WCT	COD	TxGB	CODxT	Mean
T_1	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
T_2	35.15^{a}	39.52^{b}	41.89^{a}	41.68^{a}	39.56^{a}	36.96	41.94	43.19	41.66	40.94	37.60	42.23	42.02	40.81	40.67
T_3	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
T_4	39.75^{a}	50.79^{a}	39.92^{a}	40.05^{a}	42.60^{b}	38.43	46.67	48.08	41.44	43.66	37.5	45.61	44.89	41.31	42.33
T_5	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
T_6	35.67^{a}	50.23^{a}	43.16^{a}	40.85^{a}	42.47^{b}	D	D	D	D	D	D	D	D	D	D
Mean	36.86	46.85	81.99	40.86	51.64	D	D	D	D	D	D	D	D	D	D

Table 7. contd.

Treatments	TSS/Acidity 14th day					TSS/Acidity 16th day					TSS/Acidity 18th day				
	WCT	COD	TxGB	CODxT	Mean	WCT	COD	TxGB	CODxT	Mean	WCT	COD	TxGB	CODxT	Mean
T_1	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
T_2	34.90	43.57	42.77	40.70	40.49	32.31	42.96	42.86	42.00	40.03	34.01	36.10	40.75	40.15	37.75
T_3	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
T_4	35.00	D	D	D	D	D	D	D	D	D	D	D	D	D	D
T_5	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
T_6	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
Mean	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D

Means with the same superscript are not significantly different ($P = 0.05$); D - Damaged

Table 8. Effect of light (minimal) processing and storage methods on pH of tender coconut water (TCW)

Treat-ments	pH 2nd day					pH 4th day					pH 6th day				
	WCT	COD	TxGB	CODxT	Mean	WCT	COD	TxGB	CODxT	Mean	WCT	COD	TxGB	CODxT	Mean
T_1	5.10^{a}	5.13^{a}	5.07^{a}	4.63^{a}	4.98^{a}	4.99^{a}	5.02^{a}	5.02^{a}	4.47^{c}	4.87^{ab}	4.97^{ab}	5.07^{a}	4.94^{a}	4.83^{c}	4.94^{ab}
T_2	4.94^{a}	5.13^{a}	4.94^{a}	4.81^{ab}	4.96^{a}	5.00^{a}	5.11^{a}	4.89^{a}	4.60^{bc}	4.90^{ab}	4.98^{ab}	5.13^{a}	4.59^{b}	5.53^{a}	5.06^{a}
T_3	5.18^{a}	5.13^{a}	4.98^{a}	5.10^{a}	5.10^{a}	4.57^{b}	4.91^{a}	4.92^{a}	5.07^{a}	4.87^{ab}	4.70^{b}	5.12^{a}	4.97^{a}	5.27^{ab}	5.01^{ab}
T_4	4.90^{a}	5.13^{a}	5.01^{a}	4.97^{ab}	5.00^{a}	5.07^{a}	5.06^{a}	5.13^{a}	4.87^{ab}	5.03^{ab}	4.85^{ab}	4.93^{ab}	4.87^{ab}	5.50^{a}	5.06^{a}
T_5	4.97^{a}	5.13^{a}	4.97^{a}	4.67^{ab}	4.94^{a}	5.00^{a}	5.12^{a}	4.95^{a}	5.07^{a}	5.03^{ab}	4.93^{ab}	4.72^{b}	4.74^{ab}	5.03^{bc}	4.86^{b}
T_6	5.17^{a}	5.13^{a}	5.11^{a}	5.07^{ab}	5.12^{a}	5.14^{a}	5.18^{a}	4.97^{a}	4.87^{ab}	5.04^{a}	5.05^{a}	4.85^{ab}	4.93^{a}	4.83^{c}	4.92^{ab}
Mean	5.04	5.13	5.02	4.87	5.02	4.96	5.07	4.98	4.82	4.96	4.93	4.97	4.84	5.17	4.98

Table 8. contd.

Treatments	pH 8th day					pH 10th day					pH 12th day				
	WCT	COD	TxGB	CODxT	Mean	WCT	COD	TxGB	CODxT	Mean	WCT	COD	TxGB	CODxT	Mean
T_1	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
T_2	4.95^{a}	5.11^{a}	4.87^{a}	5.27^{b}	5.05^{a}	4.80	5.20	4.93	5.30	5.06	4.82	5.2	4.87	5.33	5.06
T_3	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
T_4	4.98^{a}	5.07^{a}	4.90^{a}	5.57^{a}	5.13^{a}	4.80	5.19	4.93	5.16	5.02	4.95	5.23	5.06	5.10	5.09
T_5	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
T_6	4.87^{a}	4.90^{a}	4.93^{a}	5.21^{b}	4.98^{a}	D	D	D	D	D	D	D	D	D	D
Mean	4.93	5.03	4.90	5.35	5.05	D	D	D	D	D	D	D	D	D	D

Table 8. contd.

Treatments	pH 14th day					pH 16th day					pH 18th day				
	WCT	COD	TxGB	CODxT	Mean	WCT	COD	TxGB	CODxT	Mean	WCT	COD	TxGB	CODxT	Mean
T_1	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
T_2	4.87	5.23	5.08	5.16	5.09	4.90	5.20	5.33	5.00	5.11	4.97	5.20	5.09	4.90	5.04
T_3	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
T_4	4.93	D	D	D	D	D	D	D	D	D	D	D	D	D	D
T_5	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
T_6	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
Mean	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D

Means with the same superscript are not significantly different (P = 0.05); D-Damaged the unrefrigerated treatments showed significantly low pH. Of them T_1, T_3 and T_6 were on par (4.94, 5.01, and 4.92 respectively). Whereas T_5 (whole nut stored in open condition) showed significantly low value of pH 4.86.

On eighth day existing samples under T_2, T_4 and T_6 were on par in pH value in all varieties except COD x T. There after T_2 and T_4 followed the same trend up to the end of storage life. Under T_4 pH values were 5.23 in COD, 5.06 in T x GB, 5.10 in COD x T and 4.95 in WCT. Under T_2 pH values recorded was 4.97 in WCT, 5.20 in COD 5.09 in T x GB and 4.90 in COD x T on 18th day. Fall in pH value over storage period was negligible between T_2 and T_4.

4.2.3.6 Effect of light (minimal) processing and storage methods on the total sugar (TS%) of tender coconut water (TCW)

Effect of treatments on total sugar content of the TCW was more or less same in all varieties up to fourth day of storage and on sixth day there was little difference on the varietal response to treatments (Table 9).

In WCT, T_5 (whole nut stored in open condition) showed a significantly low value of TS content through out the storage period (4.27% on sixth day).

In COD T_3 (cling film wrapping + stored in room) and T_6 (whole nut stored in room) recorded significantly low value on sixth day (4.39% and 4.40% respectively). Variety T x GB showed no treatment difference up to sixth day. COD x T also showed the same trend up to fourth day, but with a little change on sixth day when T_3 (cling film wrapping + stored in room) showed low value (4.43%) as in the case of COD.

On eighth day only T_2, T_4 and T_6 were acceptable and T_2 gave the highest mean value of 4.52% and T_6 the lowest of 4.33% and were on par. The trend was same in all varieties.

From 10th day onward, treatments under refrigerated condition only were acceptable and T_2 gave total sugar content of 4.03% in WCT, 4.26% in COD, 4.00% in T x GB and 3.80% in COD x T on 18th day.

Table 9. Effect of light (minimal) processing and storage methods on total sugars (TS %) of tender coconut water (TCW)

Treat-ments	TS (%) 2nd day					TS (%) 4th day					TS (%) 6th day				
	WCT	COD	TxGB	CODxT	Mean	WCT	COD	TxGB	CODxT	Mean	WCT	COD	TxGB	CODxT	Mean
T_1	4.82^{ab}	5.07^{ab}	4.37^{a}	4.97^{a}	4.81^{a}	4.75^{a}	4.83^{ab}	4.33^{a}	4.87^{a}	4.70^{a}	4.45^{ab}	5.10^{a}	4.20^{a}	4.73^{a}	4.62^{ab}
T_2	5.06^{a}	5.17^{ab}	4.42^{a}	4.90^{a}	4.89^{a}	4.97^{a}	5.03^{ab}	4.36^{a}	4.73^{a}	4.77^{a}	4.62^{ab}	5.18^{a}	4.30^{a}	4.50^{bc}	4.65^{a}
T_3	5.10^{a}	4.80^{b}	4.47^{a}	4.67^{a}	4.76^{a}	4.97^{a}	4.73^{b}	4.33^{a}	4.67^{a}	4.67^{a}	4.47^{ab}	4.39^{b}	4.27^{a}	4.43^{c}	4.39^{c}
T_4	4.90^{ab}	5.03^{ab}	4.50^{a}	5.03^{a}	4.87^{a}	4.68^{a}	4.88^{ab}	4.47^{A}	4.97^{a}	4.75^{a}	4.83^{a}	5.07^{a}	4.27^{a}	4.73^{a}	4.73^{a}
T_5	4.58^{b}	5.20^{a}	4.43^{a}	5.00^{a}	4.80^{a}	4.17^{b}	5.15^{a}	4.30^{a}	4.93^{a}	4.64^{a}	4.27^{b}	4.90^{a}	4.07^{a}	4.70	4.53^{abc}
T_6	4.88^{ab}	4.93^{ab}	4.63^{a}	4.67^{a}	4.78^{a}	4.85^{a}	4.83^{ab}	4.30^{a}	4.67^{a}	4.66^{a}	4.50^{ab}	4.40^{b}	4.13^{a}	4.63^{bc}	4.42^{bc}
Mean	4.89	5.03	4.47	4.87	4.82	4.73	4.91	4.35	4.81	4.70	4.52	4.84	4.21	4.66	4.56

Table 9. contd.

Treatments	TS (%) 8th day					TS (%) 10th day					TS (%) 12th day				
	WCT	COD	TxGB	CODxT	Mean	WCT	COD	TxGB	CODxT	Mean	WCT	COD	TxGB	CODxT	Mean
T_1	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
T_2	4.41^{a}	4.93^{a}	4.20^{a}	4.53^{a}	4.52^{a}	4.33	4.90	4.05	4.47	4.43	4.27	4.56	3.93	4.23	4.02
T_3	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
T_4	4.12^{b}	4.33^{a}	4.20^{a}	4.43^{a}	4.42^{ab}	4.50	4.60	4.11	4.50	4.43	4.33	4.43	4.07	4.20	4.26
T_5	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
T_6	4.47^{a}	4.90^{b}	4.07^{a}	4.47^{a}	4.33^{b}	D	D	D	D	D	D	D	D	D	D
Mean	4.33	4.72	4.16	4.48	4.42	D	D	D	D	D	D	D	D	D	D

Table 9. contd.

Treatments	TS (%) 14th day					TS (%) 16th day					TS (%) 18th day				
	WCT	COD	TxGB	CODxT	Mean	WCT	COD	TxGB	CODxT	Mean	WCT	COD	TxGB	CODxT	Mean
T_1	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
T_2	4.07	4.53	4.00	4.06	4.17	4.00	4.46	4.00	4.00	4.12	4.03	4.26	4.00	3.80	4.02
T_3	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
T_4	4.10	D	D	D	D	D	D	D	D	D	D	D	D	D	D
T_5	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
T_6	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
Mean	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D

Means with the same superscript are not significantly different ($P = 0.05$); D-Damaged

Under T_4 (cling film wrapping + cool storage) WCT gave 4.13% on 16th day. COD, T x GB and COD x T recorded 4.43%, 4.07% and 4.20% respectively on 12th day.

Even at the storage termination stage all treatments were showing appreciable level of total sugar content in all varieties.

In general there was a slight decrease in total sugar content with storage period in all the cultivars. The trend of decrease was higher in WCT (4.89 to 4.03) under treatment T_2. Among treatment of whole nuts it was not so conspicuous.

4.2.3.7 *Effect of light (minimal) processing and storage methods on the reducing sugar (RS%) of the tender coconut water (TCW)*

Even though a marginal difference in RS content between treatments was recorded on second and fourth day in the case of WCT and COD x T the treatment effect was more or less non-significant in all varieties (Table 10).

As in the case of total sugar content, reducing sugar also showed a gradual decrease over the period in all varieties and treatments. In general the rate of reduction was more in T_3 (4.16% to 3.96%) on sixth day.

In WCT, T_1 and T_3 showed low values on sixth day and they were on par, such an effect was not there in other varieties and there was no significant difference between the treatments they ranging from 3.96% in T_3 and 4.12% in T_4.

From eighth day onwards the trend of treatment effect was almost in the same pattern of total sugar. T_4 and T_6 was showing lower values in WCT and COD. In T x GB and COD x T there was no significant difference between the treatments.

At the end of the storage life the RS content was 3.50% in WCT, 3.87% in COD, 3.61% in T x GB and 3.50% in COD x T. on 18th day in T_2. Under T_4 at the end of storage life on 12th day the mean value of RS recorded was 4.06%.

Table 10. Effect of light (minimal) processing and storage methods on reducing sugars (RS %) of tender coconut water (TCW)

Treatments	RS (%) 2nd day					RS (%) 4th day					RS (%) 6th day				
	WCT	COD	TxGB	CODxT	Mean	WCT	COD	TxGB	CODxT	Mean	WCT	COD	TxGB	CODxT	Mean
T_1	3.83^{bc}	4.40^{a}	3.87^{a}	4.33^{bc}	4.11^{c}	3.92^{b}	4.17^{b}	3.85^{a}	4.40^{a}	4.08^{a}	3.83^{a}	4.43^{a}	3.70^{a}	4.30^{a}	4.07^{a}
T_2	4.27^{a}	4.50^{a}	3.73^{a}	4.40^{abc}	4.23^{b}	4.41^{a}	4.47^{a}	3.64^{ab}	4.30^{a}	4.20^{a}	4.07^{a}	4.53^{a}	3.53^{a}	4.17^{a}	4.08^{a}
T_3	4.16^{ab}	4.23^{a}	3.82^{a}	4.13^{c}	4.09^{c}	4.01^{b}	4.17^{b}	3.80^{ab}	4.33^{a}	4.08^{a}	4.07^{a}	3.77^{c}	3.87^{a}	4.13^{a}	3.96^{a}
T_4	4.03^{ab}	4.43^{a}	3.90^{a}	4.70^{a}	4.27^{a}	3.85^{b}	4.33^{a}	3.67^{ab}	4.43^{a}	4.07^{a}	4.00^{a}	4.43^{ab}	3.73^{a}	4.30^{a}	4.12^{a}
T_5	3.65^{c}	4.47^{a}	3.70^{a}	4.57^{ab}	4.10	3.76	4.52^{a}	3.63^{ab}	4.50^{a}	4.10^{a}	3.85^{a}	4.23^{ab}	3.53^{a}	4.50^{a}	4.03^{a}
T_6	3.92^{bc}	3.37^{b}	3.73^{a}	4.17^{c}	4.05	3.98^{b}	4.30^{a}	3.60^{ab}	4.23^{a}	4.03^{a}	4.12^{a}	4.07^{bc}	3.70^{a}	4.23^{a}	4.03^{a}
Mean	3.98	4.40	3.79	4.38	4.14	3.40	4.33	3.70	4.37	4.09	3.99	4.25	3.68	4.27	4.05

Table 10. contd.

Treatments	RS (%) 8th day					RS (%) 10th day					RS (%) 12th day				
	WCT	COD	TxGB	CODxT	Mean	WCT	COD	TxGB	CODxT	Mean	WCT	COD	TxGB	CODxT	Mean
T_1	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
T_2	4.03^{a}	4.00^{a}	3.73^{a}	4.17^{a}	4.08^{a}	3.93	4.46	3.68	4.16	4.06	3.83	4.43	3.53	4.07	3.97
T_3	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
T_4	3.57^{b}	4.37^{a}	3.75^{a}	4.13^{a}	3.95^{b}	3.98	4.20	3.29	4.20	3.92	3.87	4.07	4.00	4.30	4.06
T_5	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
T_6	3.83^{a}	4.00	3.67^{a}	4.13^{a}	3.91	D	D	D	D	D	D	D	D	D	D
Mean	3.81	4.26	3.72	4.14	3.98	D	D	D	D	D	D	D	D	D	D

Table 10. contd.

Treatments	RS (%) 14th day					RS (%) 16th day					RS (%) 18th day				
	WCT	COD	TxGB	CODxT	Mean	WCT	COD	TxGB	CODxT	Mean	WCT	COD	TxGB	CODxT	Mean
T_1	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
T_2	3.67	4.10	3.5	3.76	3.76	3.57	4.00	3.53	3.72	3.71	3.50	3.87	3.60	3.50	3.62
T_3	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
T_4	3.70	D	D	D	D	D	D	D	D	D	D	D	D	D	D
T_5	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
T_6	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
Mean	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D

Means with the same superscript are not significantly different ($P = 0.05$); D-Damaged

4.2.3.8 Effect of light (minimal) processing and storage methods on the non-reducing sugar (NRS%) of the tender coconut water (TCW)

Effect of treatments on the NRS content of TCW was different in different cultivars (Table 11). On second day the effect was not significant in WCT, COD and COD x T. But in T x GB, T_3 and T_4 showed low content of NRS than other treatments.

On fourth day COD and COD x T maintained the trend. But in WCT, T_5 showed low content. Whereas in T x GB the treatment effect was not so significant.

On sixth day T_3, T_5 and T_6 recorded low values in WCT and COD. In T x GB only T_2 gave significantly highest value and in COD x T there was no such a significant difference between treatments. On eighth day NRS content was significantly low in T_6 compared to T_2 and T_4.

On subsequent days, the difference between T_2 and T_4 was only marginal. Under T_2 both WCT and COD showed the same content of NRS (0.43%) on 18th day. T x GB showed the NRS content of 0.46% on 16th days. COD x T showed 0.30% on 14th day.

As in the case of total sugar and reducing sugar there was a decrease in non-reducing sugar content of TCW with the storage period and the rate of reduction was more in T_3, T_5 and T_6 in general. Under T_2, on 18th day, the range of reduction was 0.79% to 0.43% in WCT, 0.67% to 0.46% in COD, 0.75% to 0.40% in T x GB and 0.50% TO 0.38% in COD x T. Under T_4 on 12th day the mean value recorded was 0.42%.

4.2.4 Sensory scoring for appearance, taste and aroma of TCW

Sensory scoring for the above characters was collected from the panelists consisting of five members at alternate days of storage. The scoring values were statistically analysed and presented under respective heads.

4.2.4.1 Sensory scoring for appearance of TCW

Treatment effects were statistically on par in all varieties (Table 12) on second day. On fourth day T_5 was inferior to other treatments only in the case of T x

Table 11. Effect of light (minimal) processing and storage methods on non-reducing sugars (NRS %) of tender coconut water (TCW)

Treatments	NRS (%) 2th day					NRS (%) 4th day					NRS (%) 6th day				
	WCT	COD	TxGB	CODxT	Mean	WCT	COD	TxGB	CODxT	Mean	WCT	COD	TxGB	CODxT	Mean
T_1	0.98a	0.66a	0.50a	0.63a	0.69a	0.83a	0.66a	0.50b	0.46a	0.61ab	0.61a	0.66a	0.43a	0.43a	0.53ab
T_2	0.79a	0.66a	0.75ab	0.50a	0.67a	0.55bc	0.56a	0.72ab	0.43a	0.56ab	0.55ab	0.65a	0.76a	0.33a	0.57a
T_3	0.93a	0.56a	0.64bc	0.53a	0.67a	0.93a	0.43a	0.52b	0.33a	0.55ab	0.40ab	0.55a	0.46b	0.36a	0.44bc
T_4	0.86a	0.60a	0.63bc	0.43a	0.63a	0.83a	0.55a	0.80a	0.53a	0.67a	0.50ab	0.63a	0.53b	0.43a	0.52ab
T_5	0.93a	0.73a	0.73ab	0.43a	0.70a	0.41c	0.63a	0.66ab	0.43a	0.53b	0.42ab	0.50ab	0.53b	0.40a	0.46bc
T_6	0.96a	0.56a	0.90a	0.50a	0.73a	0.73ab	0.52a	0.70ab	0.43a	0.59ab	0.54b	0.53ab	0.63b	0.45a	0.52ab
Mean	0.91	0.63	0.69	050	0.68	0.71	0.56	0.65	0.43	0.59	0.51	0.59	0.54	0.40	0.51

Table 11. contd.

Treatments	NRS (%) 8th day					NRS (%) 10th day					NRS (%) 12th day				
	WCT	COD	TxGB	CODxT	Mean	WCT	COD	TxGB	CODxT	Mean	WCT	COD	TxGB	CODxT	Mean
T_1	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
T_2	0.50[a]	0.53[a]	0.50[a]	0.33[a]	0.47[a]	0.46	0.48	0.40	0.36	0.43	0.46	0.46	0.40	0.38	0.43
T_3	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
T_4	0.53[a]	0.53[a]	0.45[a]	0.33[a]	0.46[a]	0.50	0.40	0.43	0.36	0.42	0.47	0.40	0.43	0.37	0.42
T_5	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
T_6	0.47[a]	0.33[b]	0.40[a]	0.30[a]	0.38[a]	D	D	D	D	D	D	D	D	D	D
Mean	0.46	0.47	0.44	0.32	0.42	D	D	D	D	D	D	D	D	D	D

Table 11. contd.

Treatments	NRS (%) 14th day					NRS (%) 16th day					NRS (%) 18th day				
	WCT	COD	TxGB	CODxT	Mean	WCT	COD	TxGB	CODxT	Mean	WCT	COD	TxGB	CODxT	Mean
T_1	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
T_2	0.40	0.43	0.50	0.30	0.41	0.40	0.46	0.46	0.43	0.44	0.43	0.43	0.42	0.42	0.43
T_3	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
T_4	0.40	D	D	D	D	D	D	D	D	D	D	D	D	D	D
T_5	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
T_6	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
Mean	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D

Means with the same superscript are not significantly different (P = 0.05); D- Damaged

Table 12. Effect of light (minimal) processing and storage methods on appearance of tender coconut water (TCW)

Treat-ments	Appearance 2nd day					Appearance 4th day					Appearance 6th day				
	WCT	COD	TxGB	CODxT	Mean	WCT	COD	TxGB	CODxT	Mean	WCT	COD	TxGB	CODxT	Mean
T_1	4.83a	4.83a	5.00a	4.83a	4.87a	4.50a	4.50a	4.33ab	4.83a	4.54a	4.10ab	4.20ab	4.30ab	4.33ab	4.23ab
T_2	5.00a	5.00a	4.80a	5.00a	4.95a	5.00a	5.00a	4.83a	4.83a	4.92a	5.00a	5.00a	4.83a	4.80a	4.91a
T_3	4.50a	4.83a	5.00a	4.83a	4.79a	3.67bc	4.33ab	4.30ab	4.20ab	4.13ab	3.67bc	4.10b	4.10b	4.10b	3.99bc
T_4	5.00a	5.00a	5.00a	5.00a	5.00a	5.00a	4.83a	4.83a	5.00a	4.92a	5.00a	4.83a	4.83a	5.00a	4.92a
T_5	4.50a	5.00a	5.00a	4.83a	4.83a	4.63a	4.33ab	3.47c	3.47c	3.99bc	4.25ab	4.33ab	3.47c	3.40c	3.88bc
T_6	5.00a	5.00a	5.00a	5.00a	5.00a	5.00a	4.83a	4.83a	5.00a	4.92a	5.00a	4.83a	4.83a	5.00a	4.92a
Mean	4.80	4.95	4.97	4.92	4.91	4.64	4.64	4.43	4.61	4.58	4.50	4.55	4.39	4.44	4.47

Table 12. contd.

Treatments	Appearance 8th day					Appearance 10th day					Appearance 12th day				
	WCT	COD	TxGB	CODxT	Mean	WCT	COD	TxGB	CODxT	Mean	WCT	COD	TxGB	CODxT	Mean
T_1	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
T_2	5.00a	4.83a	4.83a	4.83a	4.88a	5.00	4.83	4.83	4.17	4.71	5.00	4.83	4.83	4.83	4.87
T_3	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
T_4	4.83a	4.50a	5.00a	4.83a	4.7.9a	4.83a	4.83a	4.83a	4.83a	4.83a	4.83a	4.83a	3.17c	4.83a	4.42b
T_5	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
T_6	5.00a	5.00a	4.67a	4.50a	4.79a	D	D	D	D	D	D	D	D	D	D
Mean	4.94	4.78	4.83	4.72	4.82	D	D	D	D	D	D	D	D	D	D

Table 12. contd.

Treatments	Appearance 14th day					Appearance 16th day					Appearance 18th day				
	WCT	COD	TxGB	CODxT	Mean	WCT	COD	TxGB	CODxT	Mean	WCT	COD	TxGB	CODxT	Mean
T_1	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
T_2	5.00	4.83	4.83	4.67	4.83	4.83	4.83	4.83	4.00	4.62	4.43	4.50	4.50	4.00	4.36
T_3	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
T_4	3.17	4.67	3.83	3.33	3.75	D	D	D	D	D	D	D	D	D	D
T_5	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
T_6	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
Mean	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D

Means with the same superscript are not significantly different (P = 0.05); D - Damaged

GB and COD x T with scoring values of 3.47 in each case. On sixth day T_3 (3.67) was found to be inferior to other treatments. Under T_5 T x GB and COD x T were above satisfactory level with values 3.47 and 3.40 respectively. The highest mean values were noticed in the case of T_2, T_4 and T_6 (4.91, 4.92 and 4.92 respectively).

Effects over the period showed that the appearance of the tender coconut water under refrigerated treatments remained clear till the end of the storage period, ie, 18th day under T_2. The ranking was 4.43 for WCT, 4.50 for COD, 4.50 for T x GB, 4.00 for COD x T. Under T_4 up to 14th day the appearance was clear for WCT, COD, COD x T and T x GB with scores between 3.17 to 4.67.

In the case of un-refrigerated treatments, T_3 showed slightly cloudy appearance by fourth day of storage (4.13) in all the varieties and by sixth day T_1 also turned slightly cloudy in all varieties (4.23).

Under T_5, storage life was only up to sixth day and clarity of TCW was also maintained up to sixth day (4.92). Appearance of the TCW under T_6 was also clear till the end of storage life of eighth day (4.97).

4.2.4.2 Sensory scoring for taste of TCW

Significant difference between the treatments was noticed only at sixth day stage and T_2 and T_4 were superior to other treatments in all the varieties (Table 13).

As per the scoring recorded taste of TCW under T_2 was "good" up to 12th day (3.71) and came to "satisfactory" level (3.12) on 18th day of storage. The score was 3.00 for WCT, 3.17 for COD, 3.50 for T x GB 3.50 and 3.00 for COD x T.

Under T_4 the taste came down to satisfactory level little earlier in all varieties than in the case of T_2. The taste was below satisfactory after 12th day of storage.

In the case of nuts stored under unrefrigerated condition (T_1 and T_3) all varieties remained in the range of satisfactory level of taste up to sixth day of storage (3.54) beyond which they turned unacceptable.

Table 13. Effect of light (minimal) processing and storage methods on taste of tender coconut water (TCW)

Treat-ments	Taste 2nd day					Taste 4th day					Taste 6th day				
	WCT	COD	TxGB	CODxT	Mean	WCT	COD	TxGB	CODxT	Mean	WCT	COD	TxGB	CODxT	Mean
T_1	4.83ab	4.66ab	4.67ab	4.83ab	4.75ab	4.67ab	4.67ab	4.00c	4.83a	4.54abc	4.00cd	3.17f	3.83cde	3.17f	3.54de
T_2	4.83ab	4.67ab	4.90a	4.83ab	4.79ab	4.83a	4.5abc	4.88a	4.67ab	4.71ab	4.67ab	4.00cd	4.83a	4.17bc	4.42abc
T_3	4.80ab	4.67ab	4.65ab	4.85ab	4.75ab	4.17bc	4.67ab	4.67bc	4.83a	4.46abc	3.50def	4.00cd	4.17bc	3.17f	3.71bc
T_4	4.80ab	4.88ab	4.50ab	4.83ab	4.75ab	4.83a	4.67ab	4.83a	4.83a	4.79ab	4.67ab	3.83cde	4.83a	4.17bc	4.38ab
T_5	4.67ab	4.67ab	4.80ab	4.84ab	4.75ab	4.83a	4.83a	3.17d	4.50abc	4.33abc	4.00cd	2.50g	3.17f	3.17f	3.21e
T_6	4.83ab	4.67ab	4.83ab	4.83ab	4.75ab	4.83a	4.50abc	4.17bc	4.5abc	4.50abc	4.17bc	4.00cd	4.17bc	3.50def	3.96abc
Mean	4.81	4.69	4.73	4.80	4.75	4.69	4.64	4.19	4.69	4.55	4.17	3.58	4.17	3.56	3.86

Table 13. contd.

Treatments	Taste 8th day					Taste 10th day					Taste 12th day				
	WCT	COD	TxGB	CODxT	Mean	WCT	COD	TxGB	CODxT	Mean	WCT	COD	TxGB	CODxT	Mean
T_1	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
T_2	4.00bc	4.00bc	4.83a	4.67a	4.38a	4.00	3.83	4.50	4.17	4.13	4.17	3.67	4.17	4.00	4.00
T_3	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
T_4	4.67a	3.83c	4.50ab	4.83a	4.45a	4.17	3.67	4.50	3.50	3.96	4.17	3.67	3.50	3.50	3.71
T_5	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
T_6	3.25abc	3.17bc	3.50bc	3.33bc	3.31bc	D	D	D	D	D	D	D	D	D	D
Mean	3.97	3.67	4.28	4.28	4.05	D	D	D	D	D	D	D	D	D	D

Table 13. contd.

Treatments	Taste 14th day					Taste 16th day					Taste 18th day				
	WCT	COD	TxGB	CODxT	Mean	WCT	COD	TxGB	CODxT	Mean	WCT	COD	TxGB	CODxT	Mean
T_1	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
T_2	4.17	3.67	3.17	3.33	3.59	4.17	3.17	3.47	3.07	3.47	3.00	3.17	3.50	3.00	3.12
T_3	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
T_4	3.00	3.00	2.83	2.00	2.71	D	D	D	D	D	D	D	D	D	D
T_5	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
T_6	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
Mean	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D

Means with the same superscript are not significantly different (P = 0.05); D - Damaged

Among the treatments of whole nut, in nuts stored under open condition (T_5) taste was acceptable up to sixth day (3.96) and under T_6 (stored under room condition) it was up to eighth of storage (3.31), for all the varieties.

4.2.4.3 Sensory scoring for aroma of TCW

Aroma was found to be more sensitive to the storage methods than the other characters. It was tending to touch the satisfactory level even before the taste was coming down to satisfactory level in almost all treatments (Table 14).

Under refrigerated storage the aroma recorded 'good' up to eighth day (4.17) but maintained in the satisfactory level up to 18^{th} day (3.11) in T_2. The trend was same in all varieties. In the case of T_4, the aroma was in satisfactory condition only up to 10^{th} day (3.67) and beyond 10th day it was below satisfactory (2.65). The trend was almost same in all varieties.

In the case of T_1 and T_3 (L.P. nut under room condition) aroma was at unacceptable level after fourth day of storage. Under T_5 aroma was acceptable up to fourth day (3.54) in all varieties whereas it was acceptable up to eighth day under T_6 in all varieties (3.16).

Statistical difference between the treatments was noticed only with COD and hybrids (COD x T and T x GB) after fourth day of storage and thereafter T_2 was always significant to T_4 and other treatments were inferior to them.

4.3 EXPERIMENT- II A. UTILIZATION OF FRESH TENDER COCONUT HUSK FOR COMPOST MAKING

Evolving some methods for composting fresh tender coconut husk which is not decomposable as other agricultural wastes because of high lignin content is of much importance as it creates ecological problems when accumulated in sales points. Reports are available on composting of mature coconut husk pith by biotic and inorganic enrichment methods. Adopting these methods composting of fresh tender

Table 14. Effect of light (minimal) processing and storage methods on aroma of tender coconut water (TCW)

Treat-	Aroma 2nd day					Aroma 4th day					Aroma 6th day				
ments	WCT	COD	TxGB	CODxT	Mean	WCT	COD	TxGB	CODxT	Mean	WCT	COD	TxGB	CODxT	Mean
T_1	4.97a	4.67ab	4.83a	4.83a	4.83a	4.33abc	4.17abc	4.00bcd	4.50abc	4.25abc	3.09cd	2.17f	3.07cd	2.17f	2.63
T_2	4.83a	4.67ab	4.67ab	4.50ab	4.67ab	4.83a	4.67ab	4.83a	4.83a	4.79b	4.83a	4.17ab	3.83bc	4.17ab	4.45ab
T_3	4.83a	4.83a	4.67ab	4.83a	4.79ab	3.50de	4.00bcd	4.17bc	4.50abc	4.04ab	2.83de	3.17cd	3.00cd	2.50def	2.87de
T_4	4.83a	4.67ab	4.83a	4.83a	4.79ab	4.83a	4.50abc	4.50abc	4.67ab	4.62a	4.83a	4.17ab	4.83a	4.17ab	4.50ab
T_5	4.17bc	4.83a	4.83a	4.67ab	4.63ab	3.83cde	4.00bcd	2.17f	4.17abc	3.54cd	2.17f	2.17f	2.17f	2.00ef	2.21f
T_6	4.83ab	4.67ab	4.83a	4.67ab	4.75ab	4.83a	4.67ab	3.17e	4.17abc	4.21b	3.17cd	3.17cd	3.83bc	3.17cd	3.33cd
Mean	4.74	4.72	4.78	4.72	4.74	4.36	4.33	3.81	4.47	4.24	3.49	3.17	3.46	3.03	3.29

Table 14. contd.

Treatments	Aroma 8th day					Aroma 10th day					Aroma 12th day				
	WCT	COD	TxGB	CODxT	Mean	WCT	COD	TxGB	CODxT	Mean	WCT	COD	TxGB	CODxT	Mean
T_1	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
T_2	4.17a	3.83ab	4.50a	4.17ab	4.17ab	4.17	3.60	4.50	3.17	3.86	4.17	3.17	3.17	3.17	3.42
T_3	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
T_4	3.83ab	3.83ab	4.50a	4.17ab	4.08b	3.83	3.83	3.50	3.50	3.67	2.80	2.50	2.50	2.80	2.65
T_5	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
T_6	3.30bc	3.17bc	3.00d	3.17d	3.16bc	D	D	D	D	D	D	D	D	D	D
Mean	3.77	3.61	4.00	3.84	3.80	D	D	D	D	D	D	D	D	D	D

Table 14. contd.

Treatments	Aroma 14th day					Aroma 16th day					Aroma 18th day				
	WCT	COD	TxGB	CODxT	Mean	WCT	COD	TxGB	CODxT	Mean	WCT	COD	TxGB	CODxT	Mean
T_1	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
T_2	4.17	3.17	3.17	2.17	3.71	3.17	2.93	2.97	3.00	3.02	3.20	2.95	2.50	3.00	3.02
T_3	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
T_4	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
T_5	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
T_6	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
Mean	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D

Means with the same superscript are not significantly different (P = 0.05); D - Damaged

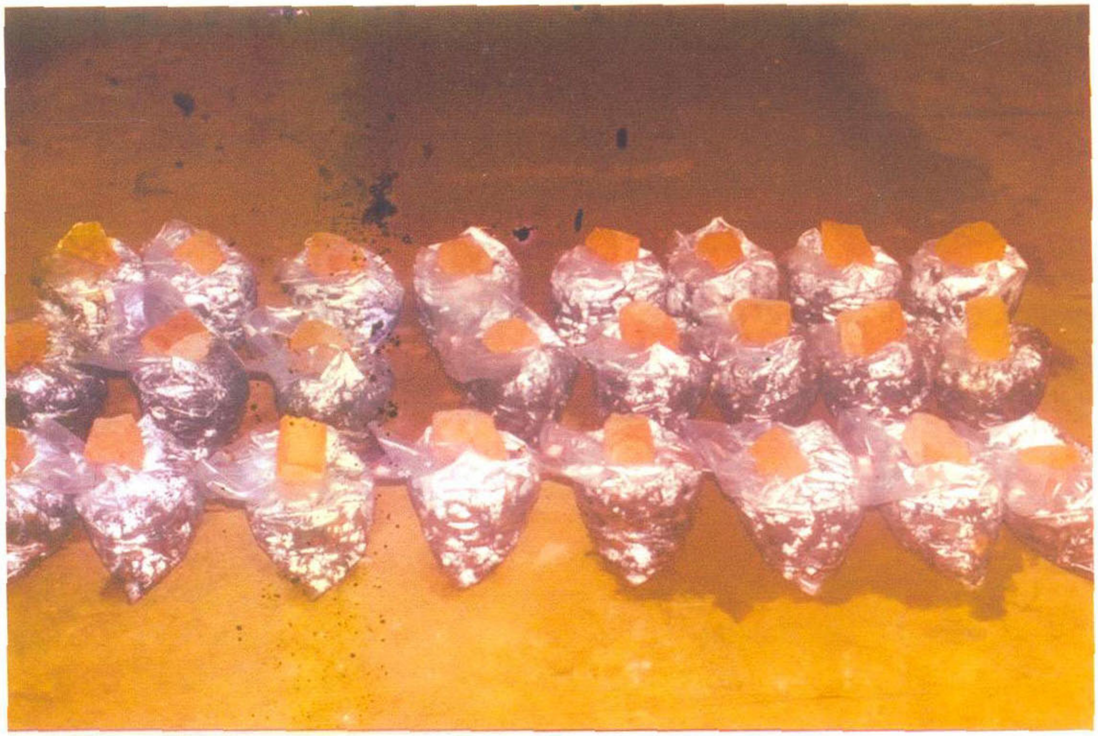


Plate 6. Decomposition studies on tender coconut husk under room condition

Plate 7. Decomposition studies on tender coconut husk under burial method

coconut husk was attempted. Observations were taken at monthly intervals for a period of four months and the data are given in table 15 (Plate 6-7).

4.3.1 Effect of composting treatments on the nitrogen content (%) of compost samples

On perusal of the data it was revealed that there was slight reduction in nitrogen content of samples over the months in T_1 (husk + cow dung in room condition) from 0.93% to 0.84% and in T_3 (husk alone in room condition) to 0.75%. The nitrogen content of other samples slightly increased over the period to:

1.08% in T_2 (husk + urea and Pleurotus),
1.07% in T_4 (husk + cow dung and buried in soil),
0.99% in T_5 (husk + urea + Pleurotus and buried in soil) and
0.90% in T_6 (husk alone buried in soil).

At all stages T_3 (husk alone under room condition) and T_6 (husk alone under burial method) recorded significantly low value than other treatments, as these samples were not added with nitrogen source to boost the decomposition process.

4.3.2 Effect of composting treatments on the organic carbon content (%) of compost samples

The difference in the organic carbon content of the composting samples were not statistically significant at fourth month as the level of decomposition was not satisfactory. The values of organic carbon content was ranging from 39.01% in T_3 and 44.00% in T_4.

4.3.3 Effect of composting treatments on the C/N ratio of the compost samples

The initial C/N ratio of TCH was 49.61. There was significant reduction in C/N ratio of compost samples over the period at fourth month.

4.3.4 Effect of treatment on the phosphorus content of samples (%) of compost samples

In general, there was a marginal decrease in phosphorus content of the samples over the period in all the treatments. It decreased marginally from 0.087 per

Table 15. Effect of composting treatment on the mineralization and content of nutrients (%) in compost samples at monthly intervals

Treat-ments	1st month			2nd month			3rd month			4th month			
	N	P	K	N	P	K	N	P	K	N	P	K	O.C
T_1	1.003^a	0.079^a	1.183^b	0.977^{cd}	0.098^b	1.080^c	0.967^{cd}	0.080^a	0.983^b	0.943^b	0.063^{ab}	1.817^b	42.03a
T_2	1.020^a	0.096^b	1.387^a	1.093^{abc}	0.087^{ab}	1.287^a	1.097^a	0.087^a	0.983^b	1.083^a	0.077^a	1.876^b	42.07a
T_3	0.763^c	0.075^c	1.173^b	0.795^d	0.068^c	1.210^b	0.764^d	0.078^b	1.227^a	0.750^b	0.077^a	1.750^a	39.01ab
T_4	0.843^{bc}	0.082^{bc}	0.853^{cd}	1.000^{ab}	0.074^c	0.863^d	1.020^{ab}	0.075^c	0.747^c	1.067^a	0.078^b	1.707^c	44.00a
T_5	0.922^{ab}	0.083^{bc}	0.957^c	1.007^{bcd}	0.079^{bc}	0.864^d	0.977^{abc}	0.074^{bc}	0.833^c	0.993^a	0.078^b	1.807^c	41.45ab
T_6	0.750^a	0.076^c	0.787^d	0.850^b	0.076^c	0.797^d	0.910^{bc}	0.079^c	0.747^c	0.921^b	0.077^b	1.750^c	42.00a
Mean	0.917	0.082	1.064	0.954	0.080	1.017	0.939	0.079	0.920	0.943	0.075	1.773	41.76

Table 15. contd.

Treat-ments	1st month			2nd month			3rd month			4th month				
	Ca	Mg	S	Ca	Mg	S	Ca	Mg	S	Ca	Mg	S	Lignin	C/N
T_1	0.787^a	0.573^a	0.240^a	0.773^a	0.553^{bc}	0.220^a	0.667^{bc}	0.567^a	0.220^a	0.647^a	0.550^a	0.203^a	10.00^a	49.85a
T_2	0.763^{ab}	0.543^b	0.220^b	0.600^c	0.540^c	0.207^a	0.583^e	0.533^a	0.207^{ab}	0.527^b	0.503^{ab}	0.194^a	9.60^a	40.73^{ab}
T_3	0.717^b	0.570^a	0.213^b	0.717^{ab}	0.560^{ab}	0.223^a	0.687^a	0.563^a	0.200^b	0.617^a	0.540^a	0.199^a	10.00^a	50.99^a
T_4	0.757^{ab}	0.560^{ab}	0.240^a	0.713^b	0.550^{bc}	0.210^a	0.680^{ab}	0.543^a	0.207^{ab}	0.633^a	0.527^{ab}	0.194^a	9.80^a	41.24^{ab}
T_5	0.697^b	0.563^{ab}	0.223^b	0.700^b	0.567^a	0.233^a	0.657^c	0.523^{ab}	0.204^b	0.617^a	0.517^{ab}	0.200^a	9.50^a	41.74^{ab}
T_6	0.700^b	0.560^{ab}	0.223^b	0.657^b	0.503^d	0.213^a	0.620^d	0.467^b	0.203^b	0.613^a	0.457^{ab}	0.196^a	10.20^a	45.60^{ab}
Mean	0.737	0.562	0.227	0.693	0.546	0.218	0.649	0.532	0.207	0.609	0.515	0.198	9.85	45.07

Means with same superscripts are not significantly different (P=0.05)

Initial content of N – 0.928 %, P – 0.087 %, K – 2.000 %; Ca – 0.780 %, Mg – 0.580 %, S – 0.240 %; Lignin – 11.02%, Org. carbon – 46.04%, C/N ratio – 49.61

cent at the initial level to 0.075 per cent, at the end of the fourth month. It indicates that process of mineralisation was not progressing considerably.

4.3.5 Effect of treatments on the potassium content (%) of compost samples

Reduction in the first month was very drastic bringing the content to 1.2 in T_1 and T_3 and 1.4 in T_2 from the initial content of two per cent. One reason for the drastic reduction in potassium content during the 1^{st} month may be due to the possible leaching of potassium from the green material. Samples of the treatments under burial method contained significantly lower level of potassium with no significant difference between the treatments. At fourth month there was no significant difference between the treatments.

4.3.6 Effect of treatments on the calcium content of samples (%) of compost samples

Data on the calcium content of the composting samples revealed a gradual decrease indicating a loss of calcium from the samples over the period in all the treatments. The original calcium content of 0.78 per cent was decreased to a mean content of 0.609 per cent may be due to the possible leaching. This decrease was more in samples supplemented with urea and Pleurotus sp. especially in incubation method.

Neither the burial method nor the incubation method had showed any advantage over the other.

4.3.7 Effect of treatments on the magnesium content (%) of compost samples at monthly intervals

The trend in the magnesium content of the composting samples were also similar to that of calcium. From the initial value of 0.78 per cent it reduced to 0.56 per cent after one month and further reduction was at a slow rate and reached to 0.52 per cent after four months.

In both the methods control treatments recorded higher value but still below the original value indicating the poor rate of decomposition.

There was no significant difference between incubation and burial methods. All the treatments had more or less same effect at the end of fourth month.

4.3.8 Effect of treatment on the sulphur content (%) of compost samples at monthly intervals

Content of sulphur in tender coconut husk was only 0.24%. In this case also the samples recorded a decreasing trend in sulphur content during the period of decomposition and came to a level of 0.20 per cent. After one month T_3 recorded minimum value, but at end of fourth month treatment had no significant difference.

4.3.9 Effect of treatments on the lignin content (%) of the compost samples

Lignin content in the decomposing samples is an important factor, as it is found to hinder the process of decomposition of organic residues. So lignin content in the samples can be taken as a measure to understand the level of decomposition.

Lignin content of the decomposed samples of fourth month was analysed and presented in Table 15. The data revealed that there was no significant difference in the lignin content of samples at fourth month. Reduction in the lignin from original content of 11.02 per cent was very minimum (9.85% mean) indicating a lower level of decomposition. However, the treatment combination of TCH + urea + Pleurotus sp. was showing comparatively maximum degradation of lignin than the other two treatments. Addition of more inoculants and a longer period of decomposition may be helpful for a high level of lignin degradation.

4.4 EXPERIMENT II B. ENSILING OF TENDER COCONUT HUSK

Crop residues have a supplementary role in feeding the cattle, after the fodder grasses. There are several reports on the addition of coconut pith in the ration given to the cattle with encouraging results. In this context developing a technology for conversion of the bulky waste of tender coconut to a cattle feed is of great

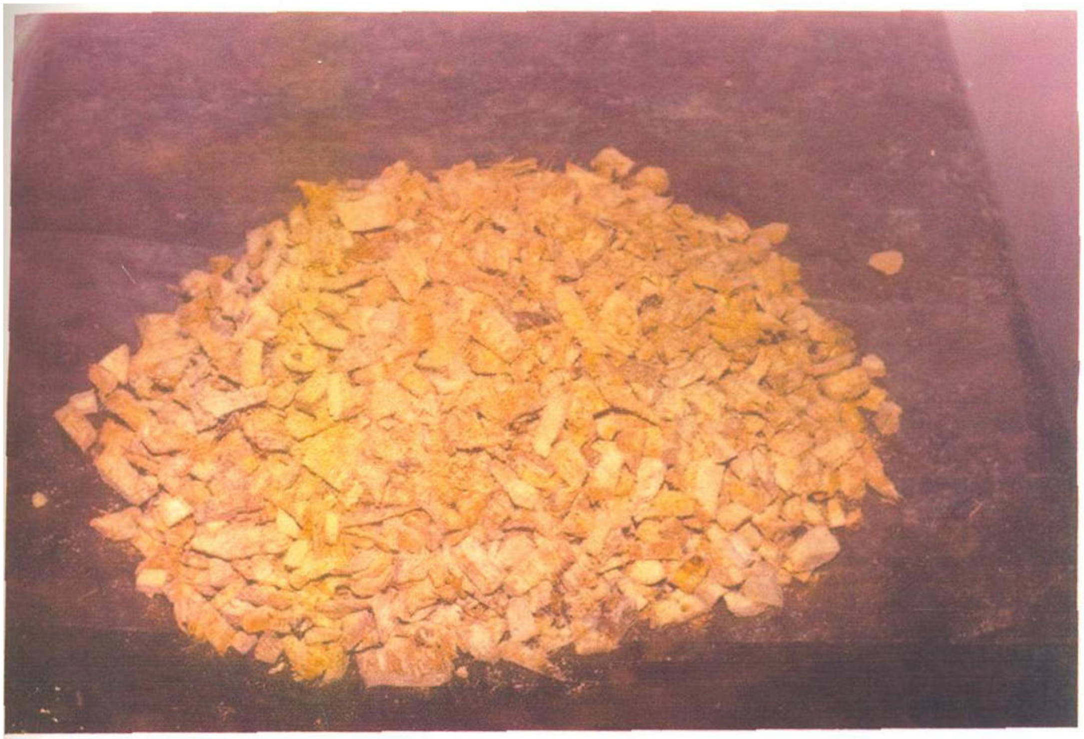


Plate 8. Tender coconut husk bits for silage making

Plate 9. Pineapple peel used for silage making

Plate 10. Silage sample vacuum packed

Plate 11. Silo kept in plastic bucket for covering with dry soil

Plate 12. Silo covered with soil and kept for fermentation

importance. With this background information tender coconut husk also had been tried for making silage (Plate 8-12).

Before recommending the silage as an alternative or supplementary feed, its nutritive value is to be understood. Therefore the TCH was analysed for it's nutritive values and the information is furnished in Table 16.

The tender coconut husk contains a good percentage of digestible carbohydrate (NFE) of 64.53%, crude protein 7.2%, and crude fat 1.73%. Mineral nutrients also were present in an appreciable level. The lignin content of the tender coconut husk was only 9.8% showing only a minimum effect on it's digestibility.

Table 16. Nutritive status of the raw tender coconut husk (%)

PH	- 5.23	NFE	- 64.53
Sugar	- 2.32 *	ADF	- 32.90
Dry matter	- 18.00	NDF	- 40.93
Crude protein	- 7.20	N	- 0.728
Crude fibre	- 16.40	P	- 0.083
Crude fat	- 1.73	K	- 1.220
Lignin	- 9.80	Ca	- 0.78
Ash	- 4.90	Mg	- 0.78
Calorific value	- 2.37	S	- 0.24

* - Green weight basis
Other values on dry matter basis

4.4.1 Effect of treatments on qualitative aspects of the silage

Effect of the treatments on the qualitative aspects of the silage such as, odour, visual symptom of fungal growth, pH and calorific value were observed and presented in the Table 17 below.

Table 17. Effect of tapioca flour, pineapple waste, molasses and jaggery on the qualitative aspect of silage

Treatments	Odour	Fungal growth	pH	Calorie (K cal g^{-1})
T_1 – TCH + tapioca flour – (5%)	Light fermented odour	Nil	5.35	3.775
T_2 – TCH + Pine-apple waste (25%)	Fermented smell with a characteristic pineapple odour	Nil	4.81	4.906
T_3 – TCH + molasses (8%)	Fermented smell with little alcoholic odour	Nil	5.04	3.470
T_4 – TCH + Jaggery (8%)	Fermented smell with alcoholic odour	Nil	5.01	4.212
T_5 – TCH alone	Fermented smell with alcoholic odour	Nil	5.20	2.373

Mean of 6 samples

Odour, visual symptom of fungal growth and pH of the silage samples were observed immediately after opening the silage after an incubation period of six weeks. All the samples were free from any visual symptom of fungal growth and had acceptable fermented odour with characteristic smell of the additive in each sample.

pH of the silage was ranging from 4.81 to 5.35, the lowest in T_2 (TCH + Pineapple waste) and the highest in T_1 (TCH + Tapioca flour). In other treatments, T_5 recorded 5.2, T_3 – 5.04 and T_4 – 5.01.

Calorific value of the samples was high in T_2 (4.906) followed by T_4 (4.212), T_1 (3.775), T_3 (3.470) and T_5 (2.373).

4.4.2 Acceptability of silage samples

Silage samples were fed to selected six cows at dry stage with two Kg. of each sample for five continuous days and the quantity consumed on each day was recorded (Table 18). All the samples were accepted but there was difference in acceptability level. On first day, being a new feed the quantity consumed was less and then improved their intake.

Table 18. Level of acceptance of different silage samples fed to the cows (sample size 2 kg)

Days	Treatments				
	T_1	T_2	T_3	T_4	T_5
1st day	0.43^{c}	1.85^{a}	1.43^{b}	1.83^{a}	0.60^{c}
2nd day	0.57^{d}	1.93^{a}	1.72^{b}	1.90^{ab}	0.90^{c}
3rd day	0.62^{c}	2.00^{a}	1.23^{b}	2.00^{a}	1.18^{b}
4th day	0.61^{c}	2.00^{a}	1.33^{b}	2.00^{a}	1.09^{b}
5th day	0.62^{c}	2.00^{a}	1.30^{b}	2.00^{a}	1.10^{b}

Means with different superscripts are significantly different (P= 0.05)

Observations recorded showed that T_2 (TCH + pineapple waste) and T_4 (TCH + Jaggery) were fully acceptable to the cattle and they were significantly superior to all other treatments. The level of acceptance of other treatments was in the descending order of T_3, T_5 and T_1.

4.5 EXPERIMENT II C. UTILISATION OF TCH AS A COMPONENT IN GROWING MEDIUM FOR ANTHURIUM

Presently commercial cultivation of anthurium is coming up well in all parts of the country. Reports say that the mature coconut husk has already being used as one of the components in growing medium for anthurium. In this study hence, the possibility of using tender coconut husk as one of the components in growing medium for anthurium was investigated.

Observations on various plant characters such as plant height, number of leaves, length of petiole and leaf area index were taken at monthly intervals. Floral characters were also recorded (Plate 13-14).

4.5.1 Effect of treatments on the height of anthurium Var. Hawaiian Red

Data recorded on plant height is presented in Table below.

Table 19. Effect of different growing medium on the height of anthurium (cm) at monthly intervals

Treat-ments	1st month	2nd month	3rd month	4th month	5th month	6th month	7th month	8th month	9th month	10th month
T_1	7.73^{a}	15.60^{ab}	18.90^{ab}	18.80^{ab}	22.20^{a}	26.90^{a}	28.50^{a}	27.7^{a}	26.60^{ab}	27.20^{a}
T_2	7.64^{a}	16.90^{a}	20.60^{a}	20.90^{ab}	21.60^{a}	29.00^{a}	30.60^{a}	30.50^{a}	29.80^{ab}	30.10^{a}
T_3	7.84^{a}	14.10^{b}	15.40^{b}	19.50^{ab}	21.40^{a}	27.90^{a}	29.70^{a}	29.10^{a}	29.60^{ab}	28.60^{a}
T_4	7.85^{a}	16.00^{ab}	19.50^{ab}	21.60^{ab}	21.90^{a}	26.30^{a}	27.20^{ab}	29.00^{a}	26.20^{ab}	26.60^{a}
T_5	8.65^{a}	17.00^{a}	20.80^{a}	22.30^{a}	23.50^{a}	28.80^{a}	29.80^{a}	28.10^{a}	30.40^{a}	30.20^{a}
T_6	7.86^{a}	15.80^{ab}	20.70^{a}	20.10^{ab}	22.90^{a}	22.25^{b}	24.00^{b}	26.10^{a}	27.20^{ab}	26.90^{a}

There was a progressive increase in plant height over the period in all treatments. But there was no significant difference between the treatments on the effect on plant height at first month but, at second month stage there was significant effect on plant height. In general, T_2 and T_5 recorded highest plant height throughout the growing period and at 10th month they recorded 30.10 cm and 30.2 cm respectively.

4.5.2 Effect of treatments on the number of leaves of anthurium at monthly intervals

Data on number of leaves are presented in Table 20. There was no significant difference between the treatments in the case of number of leaves at any of the stages. The production of leaf per plant per month was invariably one with all treatments. The mean difference from the eighth month (3.72) to the 10th month (4.57) was only 0.85.

Table 20. Effect of treatments on the number of leaves of anthurium at monthly intervals

Treat-ments	1st month	2nd month	3rd month	4th month	5th month	6th month	7th month	8th month	9th month	10th month
T_1	3.6^{a}	3.3^{a}	3.7^{bc}	4.0^{a}	4.1^{a}	4.4^{ab}	4.1^{b}	4.9^{a}	5.0^{a}	4.7^{a}
T_2	3.6^{a}	4.2^{a}	4.4^{abc}	4.0^{a}	3.9^{a}	4.8^{ab}	4.9^{b}	5.4^{a}	5.3^{a}	4.6^{a}
T_3	3.8^{a}	3.7^{a}	3.6^{c}	3.6^{a}	3.6^{a}	4.5^{ab}	5.0^{ab}	4.4^{a}	4.6^{a}	4.6^{a}
T_4	3.6^{a}	3.5^{a}	3.7^{bc}	3.4^{a}	3.7^{a}	4.9^{ab}	5.1^{a}	5.1^{a}	5.0^{a}	4.5^{a}
T_5	4.1^{a}	4.1^{a}	4.5^{ab}	4.2^{a}	3.8^{a}	4.1^{ab}	4.5^{ab}	5.1^{a}	5.1^{a}	4.7^{a}
T_6	3.6^{a}	4.8^{a}	4.6^{a}	4.2^{a}	4.3^{a}	3.4^{ab}	4.9^{ab}	4.5^{a}	4.14^{a}	4.3^{a}

Plate 13. Performance of anthurium with TCH as a component in growing medium after two months

Plate 14. Performance of anthurium plants with tender coconut husk as one of the components in growing medium

4.5.3 Effect of treatment on the petiole length of anthurium at monthly intervals

As in the case of plant height the length of petiole was also increasing up to sixth month when it was ranging from 23.4 cm in T_6 and 25.8 cm in T_1 and there was no significant difference between the treatments at that stage. After sixth month petiole length was gradually decreasing in all treatments. At tenth month too there was no significant difference between the treatments and it was ranging from 17.0 cm to 19.5 cm (Table 21).

Table 21. Effect of treatments on the length of petiole (cm) of anthurium at monthly intervals

Treat-ments	1st month	2nd month	3rd month	4th month	5th month	6th month	7th month	8th month	9th month	10th month
T_1	19.2^{a}	19.7^{a}	20.1^{bc}	20.6^{b}	25.8^{a}	25.8^{a}	23.8^{a}	21.1^{bc}	17.3^{a}	17.0^{a}
T_2	18.2^{a}	19.2^{a}	19.9^{bc}	19.7^{b}	20.8^{b}	23.4^{b}	23.1^{ab}	23.3^{ab}	18.6^{ab}	19.5^{ab}
T_3	18.8^{a}	19.4^{a}	19.5^{c}	19.9^{b}	20.7^{b}	23.0^{a}	21.3^{ab}	22.0^{ab}	19.8^{ab}	19.0^{a}
T_4	19.0^{a}	19.3^{a}	21.5^{bc}	21.2^{b}	22.9^{b}	24.4^{a}	22.9^{ab}	19.6^{c}	18.1^{ab}	18.0^{a}
T_5	18.6^{a}	19.7^{a}	24.3^{a}	23.7^{a}	23.3^{ab}	24.1^{b}	21.7^{ab}	20.1^{c}	20.5^{a}	18.5^{ab}
T_6	18.4^{a}	18.1^{a}	22.4^{ab}	21.9^{ab}	21.92^{b}	23.4^{b}	21.0^{b}	19.2^{c}	19.4^{ab}	18.5^{ab}

4.5.4 Effect of treatment on the leaf area index at monthly intervals

There was no significant difference between the treatments in the case of leaf area index up to the stage of 8th month. At ninth and 10th month T_4 recorded highest values (0.528 and 0.530 respectively) and it was superior to T_1 only at ninth month whereas it was superior to T_1, T_3 and T_5 during 10th month (Table 22).

Table 22. Effect of treatments on the Leaf Area Index of anthurium at monthly intervals

Treat-ments	1st month	2nd month	3rd month	4th month	5th month	6th month	7th month	8th month	9th month	10th month
T_1	0.553^{a}	0.687^{a}	0.666^{a}	0.583^{a}	0.537^{a}	0.411^{a}	0.460^{a}	0.335^{a}	0.350^{b}	0.379^{b}
T_2	0.430^{a}	0.469^{a}	0.654^{a}	0.640^{a}	0.655^{a}	0.435^{a}	0.561^{a}	0.432^{a}	0.437^{ab}	0.443^{ab}
T_3	0.391^{a}	0.445^{a}	0.558^{ab}	0.627^{a}	1.163^{a}	0.402^{a}	0.453^{a}	0.375^{a}	0.392^{ab}	0.354^{b}
T_4	0.426^{a}	0.377^{a}	0.519^{b}	0.626^{a}	1.015^{a}	0.420^{a}	0.412^{a}	0.451^{a}	0.528^{a}	0.530^{a}
T_5	0.581^{a}	0.407^{a}	0.486^{b}	0.536^{a}	0.687^{a}	0.602^{a}	0.453^{a}	0.338^{a}	0.421^{ab}	0.331^{b}
T_6	0.422^{a}	0.416^{a}	0.500^{b}	0.445^{a}	0.362^{a}	0.465^{a}	0.461^{a}	0.454^{a}	0.398^{ab}	0.434^{ab}

4.5.5 Effect of treatments on the flower characters in anthrium

Observations on flowering and flower characters such as, days taken for first flowering, interval of flower production, number of flowers produced per plant, length of flower stalk, length of spadix and size of spathe were observed and presented in the Table 23.

Table 23. Effect of treatments on flowering and floral characters of anthurium

Treatments	Days taken for flowering	Interval of flower production (days)	No. of flowers produced	Length of flower stalk (cm)	Length of spadix (cm)	Spathe size (cm^2)
T_1	171.143[a]	29.143[a]	3.143[a]	24.286[b]	1.79[c]	26.876[a]
T_2	174.429[a]	25.286[a]	2.429[a]	26.000[ab]	4.97[a]	25.357[a]
T_3	174.571[a]	23.714[a]	2.857[a]	27.429[a]	5.20[a]	23.444[ab]
T_4	175.286[a]	26.000[a]	2.714[a]	24.571[ab]	3.33[a]	27.634[a]
T_5	167.143[a]	25.286[a]	3.143[a]	24.714[ab]	1.81[c]	29.356[a]
T_6	166.714[a]	23.286[a]	2.286[a]	27.714[a]	4.14[ab]	27.937[a]

4.5.5.1 Effect of treatments on the days taken for flowering

There was no significant difference between the treatments on the number of days taken for flowering though the less number of days was taken in T_6 (166.7) and minimum days (175.3) in the case of T_4.

4.5.5.2 Effect of treatments on the intervals of flower production in anthurium

In this case also there was no significant difference between the treatments. The interval was shorter in T_6 (23.3 days) and longer in T_1 (29.1 days).

4.5.5.3 Effect of treatments on number of flowers per plant in anthurium

There was no significant difference between treatments on flower production. The highest number (3.143) was noticed in T_1 and T_5.

4.5.5.4 Effect of treatments on the length of flower stalk in anthurium

With respect to the length of flower stalk T_4 and T_5 were significantly inferior (21.5 cm, 21.7 cm respectively) to other treatments. T_3 and T_6 recorded higher values of 27.4 cm and 27.7 cm respectively.

4.5.5.5 Effect of treatments on length of spadix in anthurium

Length of spadix was significantly low in T_1 and T_5 (1.79 cm, 1.81 cm respectively). Other treatments were on par with highest value in T_3 and T_2 (3.2 cm and 4.97 cm respectively).

4.5.5.6 Effect of treatments on the size of spathe in anthurium

Size of spathe was significantly less in T_1 (16.876 sq. cm) and that of other treatments were on par. Higher values were recorded by T_5, T_6 and T_4 (29.356, 27.937 and 27.634 sq. cm respectively).

On perusal of the data on the growth and flower characters it could be seen that the inclusion of seventh month old tender coconut husk in the growing medium for anthurium was as good as the inclusion of mature coconut husk and other components included in the study. T_1 with Tile bits and TCH, T_2 with Tile bits and MCH, T_6 with TCH alone (all with one part of standard potting mixture) had no significant effect over the other in any of the growth characters especially at seventh month i.e. the end of the vegetative phase and starting of flowering. The treatments with inclusion of charcoal and also with combining of TCH and MCH had no significant difference.

4.6 EXPERIMENT II D. UTILISATION OF TCH AS A MEDIUM FOR MUSHROOM CULTIVATION

Two media were used for growing the edible mushroom spp. *P. sajor caju* and *P. florida* to asses the suitability of TCH as mushroom medium and to compare it's biological efficiency with that of paddy straw (Plate 15-18).

Plate 15. Performance of *Pleurotus florida* with TCH as medium

Plate 16. Performance of *Pleurotus sajor caju* with TCH as medium

Plate 17. Performance of *Pleurotus florida* with paddy straw as medium

Plate 18. Performance of *Pleurotus sajor caju* with paddy straw as medium

4.6.1 Effect of media on the days taken for spawn running

The mean number of days taken for spawn running was 13.67 days. There was no significant difference between the treatments in the days taken for the spawn running, though T_2, (TCH with *P. florida)* took 14.17 days for spawn running (Table 24).

Table 24. Effect of different media on the performance of mushroom species

Treatments	Days taken for			Yield (g)	B:E (%)
	Spawn running	1st harvest	Last harvest		
T_1 TCH + *P. sajor caju*	13.83[a]	20.50[a]	39.83[b]	395.00[ab]	39.58[ab]
T_2 TCH + *P. florida*	14.17[a]	20.67[a]	48.00[a]	331.67[b]	33.17[b]
T_3 Paddy straw + *P. sajor caju*	13.33[a]	20.17[a]	41.17[b]	402.50[ab]	40.25[ab]
T_4 Paddy straw + *P. florida*	13.33[a]	20.00[a]	43.33[b]	420.00[a]	42.00[a]
Mean	13.67	20.34	43.08	387.29	38.75

4.6.2 Effect of media on the days taken for the harvest of mushroom

There was no significant difference between the media or between the mushroom species on the days taken for the first harvest. The average days taken for first harvest was 20.34. TCH found to take slightly more time for first harvest with both *P. sajor caju* and *P. florida* (20.5 and 20.67 respectively) (Table 24).

4.6.3 Effect of media on the days taken for the last harvest of mushroom

There was significant difference between the treatments in days taken for last harvest. The mean days taken was 43.08. The days taken for the media of TCH with *P. florida* was significantly high (48.0 days) (Table 24).

4.6.4 Effect of media on the yield of mushroom

Significant difference was noticed in the yield of mushroom with different media. The mean yield of mushroom was 387.29 gram/bed. Highest yield was obtained for paddy straw with *P. florida* (420.0 g) but, with TCH *P. florida* gave the significantly low yield of 331.67 g/bed. As far as *P. sajor caju* was considered there was no significant difference between TCH and paddy straw (395.00 g and 402.5 g respectively). Therefore for TCH media *P. sajor caju* was found to be more suitable mushroom spp. (Table 24).

4.6.5 Biological efficiency (BE)of the media for mushroom culture

As in the case of yield, biological efficiency of the media was more for paddy straw with *P. florida* (42.00 per cent) and it was the least in TCH with *P. florida* (33.17%). As far as *P. sajor caju* is concerned both the media were on par in their BE, with 40.25% in paddy straw and with 39.58% in TCH (Table 24).

4.6.6 Sensory scoring for quality parameters

Sensory scoring for the colour and appearance and also for taste and flavour were observed using a Hedonic scale.

4.6.6.1 Sensory scoring for colour and appearance of mushroom

Scoring was done by panelists consisting of five members and scoring in general was found as follow.

Quality	Media			
	TCH + *P. s c*	TCH + *P. f*	Straw + *P.s c*	Straw + *P. f*
Colour and appearance of mushroom	3	5	3	5

(Mean of 5 figures)

The above scoring points indicated that both the strains of mushroom had these characteristic colour and appearance and the media had no influence on it. The strain *P. florida* had its characteristic pure white (5) colour and appearance and *P. sajor caju* had its slightly greyish (or greyish white) (3) colour and appearance.

4.6.6.2 Sensory scoring for taste and flavour of mushroom

The mushroom harvested were freshly used for frying with coconut oil adding only salt. Spices were not added, to have a clear assessment, without the influence of spices on the taste and aroma. The scoring was done by the five member panalist as under.

Quality	Marks			
	TCH + *P. s c*	TCH + *P.f*	Straw + *P. s c*	Straw + *P.f*
Taste and flavour	5	4.8	4.8	4.8

(Mean of 5 figures)

The above scoring indicates that both species of mushroom had appreciably high level of taste and aroma with both of the media. Strain *P. sajor caju* had highest scoring (5 – very good) with TCH. In all other cases it was nearing very good (4.8). TCH as a substrate for mushroom growing had proved to be desirable, having appreciable level of quality.

4.7 EXPERIMENT IIE. FIREWOOD VALUE OF DRY TENDER COCONUT HUSK

As other coconut crop residues, the husk of tender coconut is also commonly used as household fuel materials by the weaker section dwelling near by the tender coconut sales point. It was intended to find out the fuel value of dry tender coconut shell, which is to be left out as a waste at sales points of the LP nuts, as an observational trial.

As a matter of general interest, in addition to the dry tender coconut shell, caloric value of all other by-products (crop residues) of coconut palm used as fuel material were observed and presented in the Table 25.

Besides calorific value of the materials, other fire wood characteristics such as ash content, moisture content and specific gravity of the air dry materials were observed which are necessary to work out their fuel value index. The calorific value of the material is observed on dry matter basis, at zero moisture level. The fuel value index is a function of calorific value with factors such as specific gravity, moisture and ash content of the air dry material (i.e. in commonly used fire wood condition) when we get maximum recovery of energy is obtained.

$$\text{FVI} = \frac{\text{Calorific value (K.J. } g^{-1}) \times \text{sp. gravity}}{\text{Ash } (g.g^{-1}) \times \text{moisture } (g.g^{-1})}$$

Table 25. Firewood characteristics of coconut by-products

Materials	Calorific value K.cal g^{-1}	Ash % (Dry matter basis)	Moisture % (air dry basis)	Specific gravity	Fuel value index
Mature shell	5.300	0.72	7.60	1.23	49975
Tender shell	3.985	1.70	8.40	0.50	5838
Mature husk	2.637	6.00	18.00	0.31	317
Tender husk	2.373	4.90	12.00	0.28	473
Fronds	3.668	7.50	16.00	0.55	704
Leaves	2.287	4.00	10.00	0.25	598
Spathe	4.149	2.32	14.20	0.44	2302
Bunch stalk	4.608	2.67	15.00	0.67	3225
Fibrous sheeth	3.041	7.00	8.00	0.30	682

Mean of three trials

The above data reveal that the dry tender coconut shell recorded a fuel value index (FVI) of 5838, coming next to the mature shell (49975). It was followed by the bunch stalk (3225) and the spathe (2302).

Tender coconut husk recorded higher fuel value index (473) than the mature husk (317).

Fronds, leaves and fibrous sheath of coconut recorded fuel value index of 704, 598 and 682 respectively.

4.8 EXPERIMENT III. PILOT TESTING OF LP TECHNOLOGY FOR TENDER COCONUT

Lightly processed tender coconut packaged in ventilated LDPP covers and stored under refrigeration was found to be the best out of all treatments. This product was subjected to pilot testing serving 100 numbers of LP tender coconut to the consumers on every alternate days. This was continued up to 20th day of storage. The level of acceptability was collected through a questionnaire method. Consumers for this study was selected so as represent a collective sample of the public comprising of Govt. employees, students, farm labourers and the public who visited Agri. Tech. Information Centre, mannuthy which was chosen as the venue for the study (Plate 19-20).

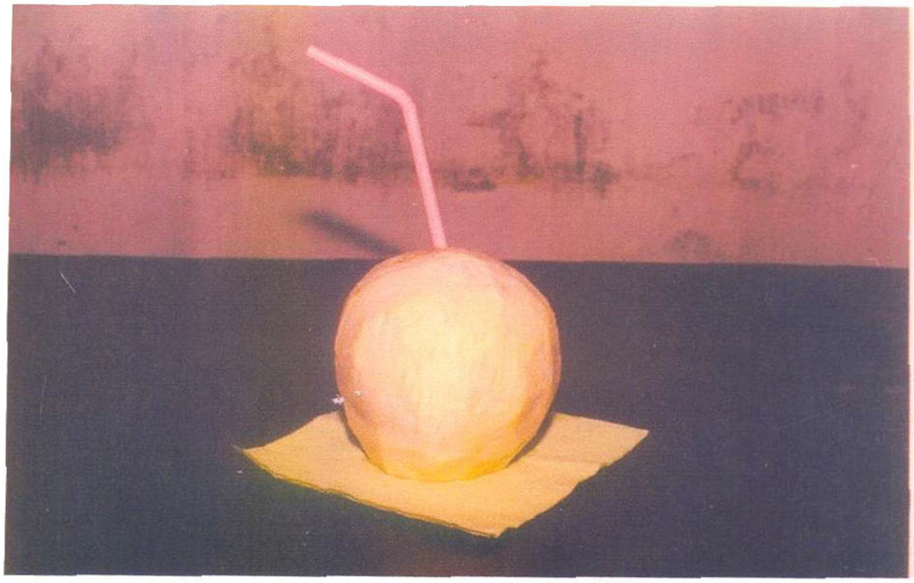


Plate 19. Chilled LP tender coconut as ready to serve beverage

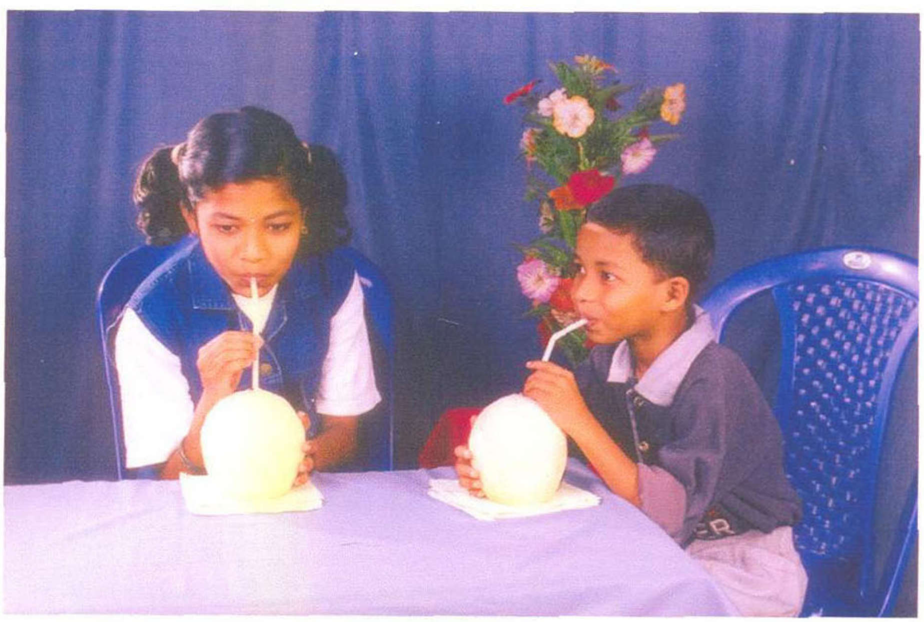


Plate 20. LP tender coconut under pilot testing

Consumers opinion was collected on the following 6 aspects.

1. Acceptance of the product in general (overall response)
2. Comparison with ordinary whole nut water
3. Comparison with synthetic beverages
4. Comparison with other fruit juices
5. Willingness to purchase and
6. Any inconvenience for consuming minimally processed and refrigerated tender coconut.

4.8.1 Overall response

The data on the observations are presented in Table 26. During the period of study 20-52% of the consumers recorded it as "very good, 44-68% as good 4-28% as "satisfactory" up to 16th day. Acceptability level of LP tender coconut fell below "very good" after 16 days and below "satisfactory" after 18 days when only 4% of the consumers recorded it as below "satisfactory". Where as 52% recorded as "satisfactory" and 44% recorded as "good".

On 20th day 57% of the consumers ranked it as "satisfactory", 35% recorded as "dislike" and only 8% recorded as "good".

4.8.2 Comparison of quality of LP tender coconut with ordinary tender coconut

Between 70-98% of the consumers opined that quality of LP tender coconut was "similar" to that of ordinary tender coconut at varying duration of storage. On 18th day 70% of the consumers ranked it as "similar" and 30% recorded as "inferior". On 20th day of storage all the consumers recorded it as "inferior" in quality.

4.8.3 Comparison of LP tender coconut with other synthetic beverages

None of the consumers recorded LP tender coconut as inferior to synthetic beverages, instead ranked it as "best" by 48%, "better" by 32% and "similar" by 20% up to 18th day. During the period of study consumers ranging from 20-64% accepted it

Table 26. Mean response of consumers during pilot testing of lightly (minimally) processed tender coconut stored under refrigerated condition

Ranks	2nd day	4th day	6th day	8th day	10th day	12th day	14th day	16th day	18th day	20th day
Overall response (%)										
Very good	44	36	52	20	28	32	32	40	--	--
Good	56	64	44	68	44	60	52	48	44	08
Satisfactory	--	--	04	12	28	08	16	12	52	57
Dislike	--	--	--	--	--	--	--	--	04	35
Comparison of quality of LP nut with ordinary tender nut water										
Similar	98	94	92	87	86	88	70	72	70	--
No	02	06	08	13	14	12	30	28	30	100
Comparison of LP nut with other synthetic Cool drinks										
Best	64	44	36	28	28	20	24	38	48	--
Better	32	52	60	60	52	58	68	46	32	--
Similar	04	04	04	12	20	22	08	16	20	22
Inferior	--	--	--	--	--	--	--	--	--	78
Acceptability of LP tender nut compared to other fruit juices like Orange, Grapes and Pineapple										
More acceptable	90	70	80	70	70	64	84	60	48	--
Similar	08	24	16	28	24	30	08	34	40	20
Less acceptable	02	06	04	02	06	06	08	06	12	80
Willingness to purchase LP refrigerated tender nut if available in the market										
Yes	96	96	84	92	96	84	92	88	48	16
No	04	04	16	08	04	16	08	12	52	84
Any inconvenience in consuming minimally processed, refrigerated tender nut										
Yes	--	--	--	--	--	--	--	--	--	--
No	100	100	100	100	100	100	100	100	100	100

Total number of response is 100. Data is presented in %.

as "best" to other synthetic cool drinks and 32-68% noted as "better" to synthetic beverages. Only 2-22% expressed as "similar" on 18th day. On 20th day 22% recorded as "similar" and 78% as "inferior".

4.8.4 Acceptability of LP tender coconut compared to other fruit juices like orange, grapes and pineapple

During the entire study period very few consumers recorded it as "less acceptable" than other fruit juices i.e.2-8% up to 16th day. On 18th day 48% recorded as "more acceptable", 40% as "similar" and 12% as "less acceptable".

On 20th day 20% of the consumers recorded as "similar" and % recorded as "less acceptable".

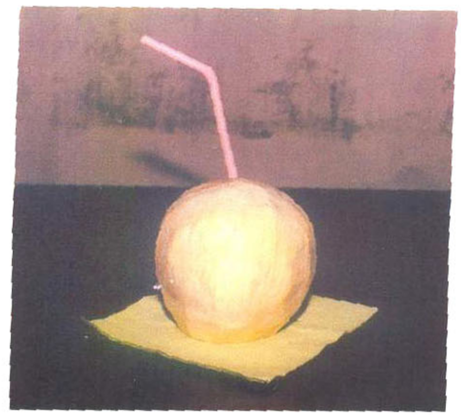
4.8.5 Willingness to purchase this LP refrigerated tender coconut if available in the market

Willingness of the consumers to purchase the LP refrigerated tender coconut was ranging from 48-96% up to 18th day of study (On 16th day 88% and 18th day 48%). On 20th day only 16% were willing to purchase it.

4.8.6 Any inconvenience for consuming minimally processed and refrigerated tender coconut

None of the consumers expressed any inconvenience while consuming LP tender coconut during the pilot study.

Discussion



5. DISCUSSION

Tender coconut water, the liquid endosperm, is the most nutritious wholesome thirst quenching drink that the nature has provided to the mankind to fight the sultry heat in the tropics. It also provides sugar, minerals vitamins in easily digestible form.

Popularisation of tender coconut has a wide and bright scope in India. Though the lions share of production in India is from four South Indian states, tender coconut the delicious thirst quenching drink, is in demand throughout India. Fortunately, as the hottest part of the year is experienced at various months in South, East, Central and North Indian states there is a regular and continuous demand for tender coconut in India.

Unfortunately, possibility of this sector is not properly utilised so far for various reasons. The soft drink industry in India has shown a phenomenal growth rate (10%) in recent years. A wide range of aseptically packaged drinks with artificial/ natural flavouring agents and preserved fruit juices are available in the market. But the tender coconut stands out as the only natural drink which is available throughout the year.

Present consumption of tender coconut is reported to be only 10 per cent of the total production. Demand can be increased many folds by adopting appropriate strategy for value addition and marketing. Whole tender coconut being a bulky produce it is very inconvenient to serve it as a ready to drink product. Tender coconut is marketed as a way side drink where quality is not assured or maintained. The bulky waste, i.e., the empty tender coconut which comes more than 60 per cent of the total nut in volume and weight is thrown out carelessly at the consumption point in major cities, tourist points and other public places. This create serious garbage problems and the local authorities are forced to spent a sizable amount to remove many truck loads of empty tender coconuts every day.

Transportation of tender coconut to distant markets also not so easy and hence, popularisation of tender coconut and exploitation of marketing potential in the non-traditional areas are not still achieved. A lot of off farm employment opportunities can be created by value added tender coconut trade and the related activities. It is sure that there is a bright scope for tender coconut business in India, where people are aware of the nutritional and health benefits of tender coconut. Popularisation of tender coconut can be a single major approach to improve earnings from coconut farming in India. If entire Indian population consumes 12 tender coconut a year the entire coconut production in the country will be used up only by the sector. This calls for concerted efforts to popularize tender coconuts throughout the country.

The concept of minimal processing of fruits and vegetables which is gaining momentum now-a-days was fitted appropriately to tender coconut in the present study. Minimal processing made the tender coconut handy due to the reduction in weight and volume and reduced the transportation cost. It was well accepted as a natural convenient drink when served as a chilled beverage. The byproduct of the minimal processing of the tender coconut, the tender coconut husk, was also put for diversification through different procedures.

Thus the present study was undertaken with the objective of developing the integrated minimal processing technology for tender coconut by which the tender coconut could be made available as a chilled beverage in a convenient attractive form without disturbing the nutritional qualities. At the same time, it was attempted to take care of the garbage problems by putting to use the trimmed off tender coconut husk at the minimal processing centre for further value addition.

The results obtained from the different experiments of the study, after the statistical analysis of the date recorded, were subjected to interpretation in the light of previous work and logical reasoning. This discussion is presented in the following pages. It was specially tried to bring out points of information that has practical application in the present situation.

PRELIMINARY OBSERVATIONS

A. Biometric character of the tender coconut

Before coming to the packaging and storage studies, the share of the different components of tender coconut such as husk, shell, kernel and water in all the selected varieties were recorded. The major purpose of these observation was to find out how much of the volume and weight of the tender coconut can be reduced and also how much of the garbage accumulation at consumption point can be reduced by way of minimal processing. It was observed that by trimming of husk there was 55.5 per cent reduction in weight and 61.3 per cent reduction in volume. Another practical importance of this study was 78.97 per cent of the total husk was trimmed off at the processing centre reducing the garbage accumulation at consumption centre to 21.03 per cent. The above observations indicate the possibility of convenient handling of tender coconut in processing, dealing and consumption. The processed tender coconut can be conveniently arranged in plastic crates and accommodated twice the number of whole tender coconut in truck space for transportation reducing the cost of handling and transportation. It also reduces the cost of transportation of garbage accumulation at consumption point.

The observations regarding the volume of tender coconut water showed that the volume of the tender coconut was in the decreasing order from WCT, T x GB, COD x T and COD, the volume of water content was in the order of WCT, COD x T, COD and T x GB ranging from 360.83ml to 304.17 ml.

This observation indicate that the size of the whole tender coconut gives no indication of the water content as the inner nut size is reduced corresponding to the thickness of the husk. Similar results were also reported by Damodaran *et al.* (1993). In the present study it was observed that the specific gravity of the tender coconut water did not vary significantly among the varieties studied.

B. Biochemical characters of the tender coconut water (TCW)

Regarding the biochemical characters of TCW total soluble solids (5.10° Brix), total sugar content (5.0%) and sensory scoring for taste (5.0%) was high in COD. This was closely followed by tall and other varieties. TSS/acidity ratio a parameter of acceptance was high in T x GB (52.32) followed by WCT and COD x T. As lion share of the tender coconut consumption is still tall and hybrid varieties than the COD this observation does not make variation in the tender coconut consumption and trade.

Experiment-I. Standardisation of packaging and storage requirements for lightly (minimally) processed tender coconut in selected varieties

Effect of minimal processing and storage methods on the storage life and quality parameters of the tender coconut of selected varieties were recorded. The observation that ventilated packaging with cool storage of LP tender coconut had the longest storage life of 18 days compared to other treatments was encouraging and adoptable for popularization of LP technology for tender coconut. (Fig. 2)

It is a fact that PLW is influenced by ambient temperature. The treatment kept under refrigerated conditions can reduce the PLW rate resulting the long storage life due to low respiration rate and low transpiration loss. The development of off flavour and slight cloudiness to the tender coconut water in the case of LP tender coconut stored under room condition was the combined effect of husk trimming and storage under ambient temperature. The high rate of respiration, excessive drying up of thin layer of husk due to direct influence of room temperature resulted in acceleration of physiological activities in the LP tender coconut might have accelerated the physiological activities in the nut water causing early exhaustion of enzymes and hormones leading to deterioration of the quality. May be for the same reason the whole tender coconut kept under open condition also showed the same result on sixth to eighth day after storage.

The trend in physiological loss of weight (PLW) was same in all the varieties and treatments. The rate of PLW was also found to be associated with the reduction in TSS/acidity ratio and development of off flavour in TCW (Fig. 3).

Ben-Yohoshua *et al.* (1983) also reported that the declining water potential in the husk due to higher rate of transpiration and other biological changes were the

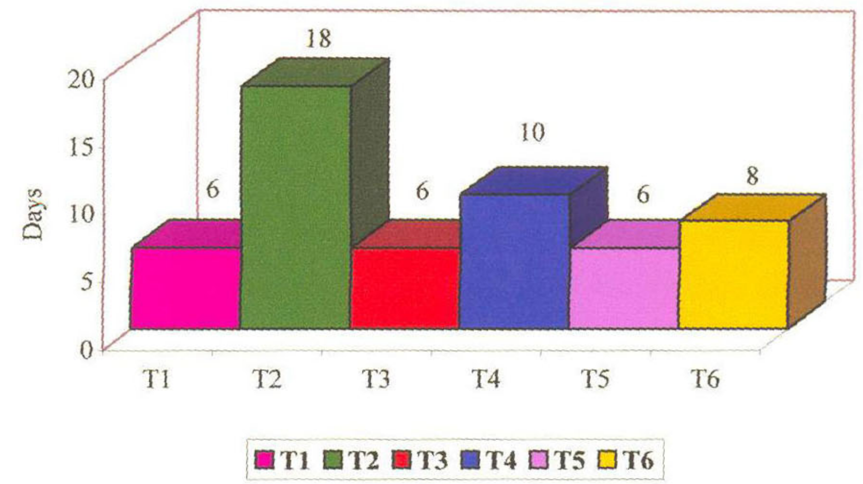


Fig. 2. Storage life of tender coconut under different treatments

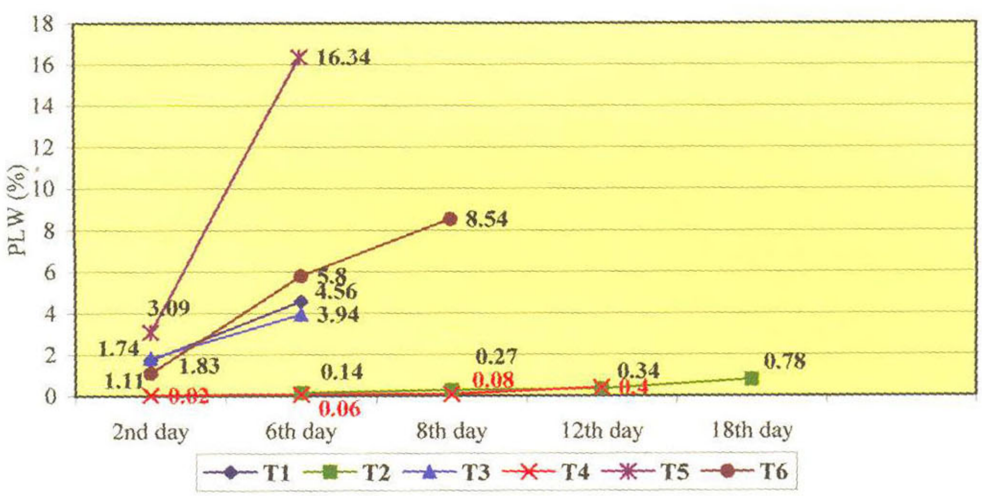


Fig. 3. Effect of light (minimal) processing and storage methods on physiological loss of weight (PLW %) of tender coconut (TC)

reasons for decline in quality of tender coconut. In conformity with this, in the present study also there was a significantly declining trend in all qualities in treatments other than those under refrigerated condition. The same trend was noticed in case of TSS in all varieties and the reduction was less evident in storage under refrigeration (Fig.4).

TSS/acidity ratio which decides the acceptability of the tender coconut water is a combined effect of the levels of TSS and acidity of the tender coconut water. This ratio was high in COD (46.51) and it was followed by COD x T (41.29), T x GB (40.15) and WCT (40.15). This ratio was slightly decreasing in all varieties over storage period in all treatments other than under refrigerated condition. This was due to increase in acidity in TCW in non- refrigerated storage. In treatments under refrigerated storage TSS/acidity ratio showed no significant difference over the period though it was in the decreasing trend.

In the case of total sugars (TS) content of TCW also all the treatments and all the varieties were showing slight reduction in TS content, with storage period on sixth day (Fig. 5). But reduction in the level of TS was not the criteria for getting the TCW unfit for consumption as in treatments other than refrigerated storage, the TS content was high (4.39 to 4.60%) even at sixth day stage and were turned unacceptable. The reducing sugar and also non-educing sugar contents were showing the same trend with all varieties and treatments. Similar trend had also been reported by Raju (1998), the reduction in sugar content of TCW may be due to the reason that it might have been used up as a source of energy for physiological activities in the tender coconut.

Colour of the LP tender coconut could be retained as clear white without any browning when dipped in KMS + citric acid solution for three minutes throughout the storage period under refrigeration. Tongdee *et al.*, (1991) also reported similar findings in tender coconut. Sensory scoring was taken for appearance (clarity), taste and aroma of TCW. Appearance of the TCW was satisfactorily high without any cloudiness for LP tender coconut in ventilated packaging and refrigeration indicating the low rate of physiological activities in TCW during storage period. It is also

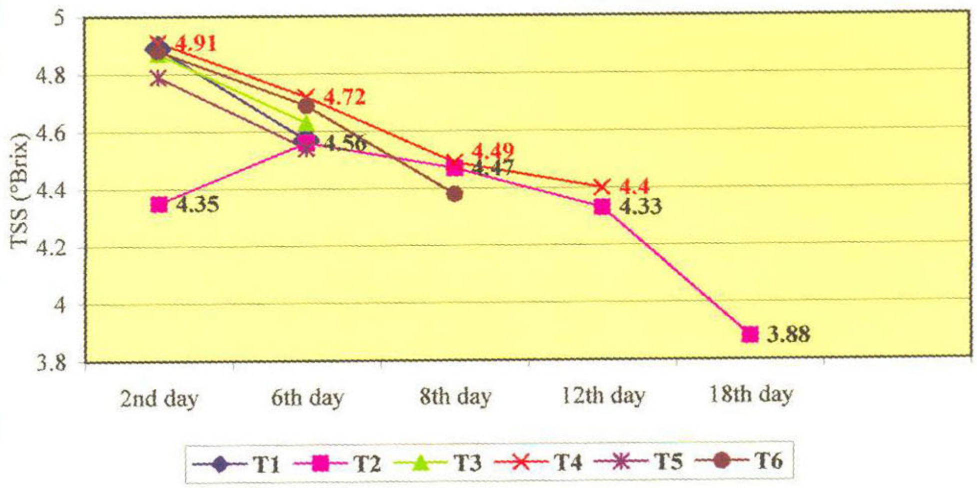


Fig. 4. Effect of light (minimal) processing and storage methods on total soluble solids of tender coconut water (TCW)

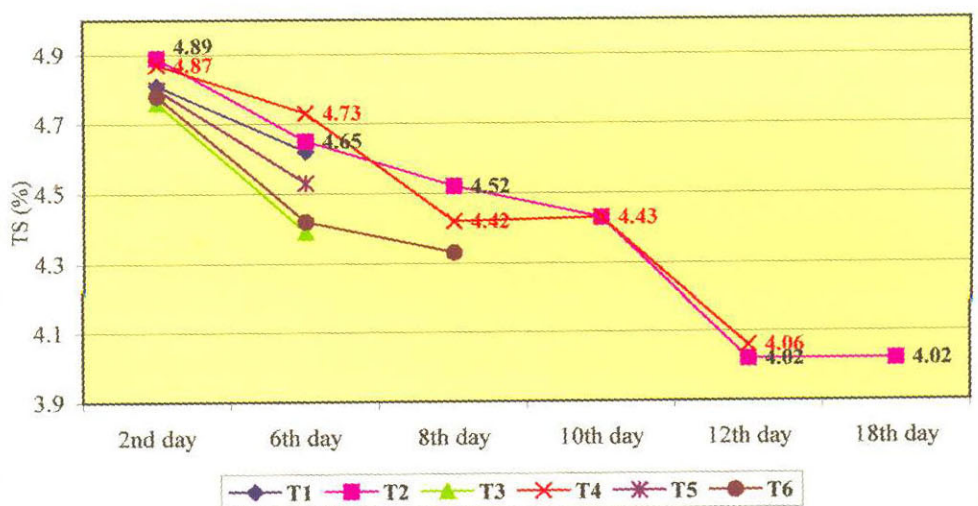


Fig. 5. Effect of light (minimal) processing and storage methods on total sugars of tender coconut water (TCW)

reported by many workers (Rajasekharan and Pandalai, 1960) that cold storage could be helpful to retain the freshness and quality of the tender coconut.

Acceptance of taste and aroma of TCW were also in the same pattern reaffirming that there was no biochemical degradation of any component of the tender coconut water to the level of making any undesirable changes in the taste and aroma of TCW (Fig. 6 and Fig. 7).

The shorter storage life of LP tender coconut under cling film wrapping and cool storage was due to low level of taste and aroma of TCW which can be attributed to the ill effects caused by the blockage of ethylene and carbon dioxide evolved inside the wrapping combined with the lack of contact with oxygen. This observations were in conformity with the earlier reports by Cameron et al. (1995) in storage studies on tender coconut.

Possibility of extending shelf life of fruits and vegetables with ventilated packaging was also reported by Singh and Narayana (1995). It was also reported that low temperature storage was found to reduce the respiration rates, PLW and post harvest deterioration in grapes by Berry and Aked (1996).

It shows that minimal processing combined with treatment in KMS + citric acid solution, packaging in ventilated PDPP cover and refrigeration helped to keep up all the quality parameters of TCW in acceptable range without the development of any cloudiness or off flavour to the TCW till the end of the storage life of 18 days It also helped to make the LP nut attractive, handy and convenient to serve as a chilled RTS beverage. By adopting this technology consumption of tender coconut can be popularized and increased to many folds to the benefit of farmers, traders and consumers.

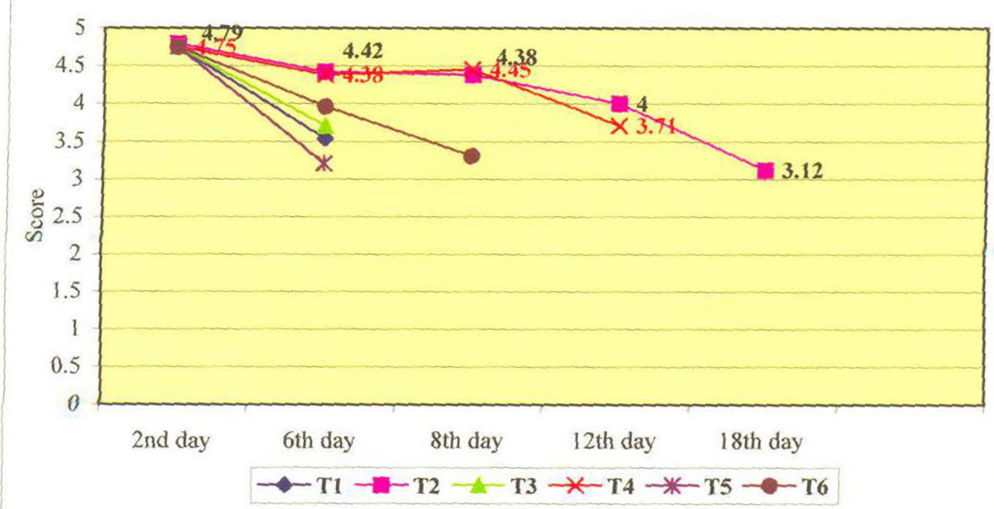


Fig. 6. Effect of light (minimal) processing and storage methods on taste of tender coconut water (TCW)

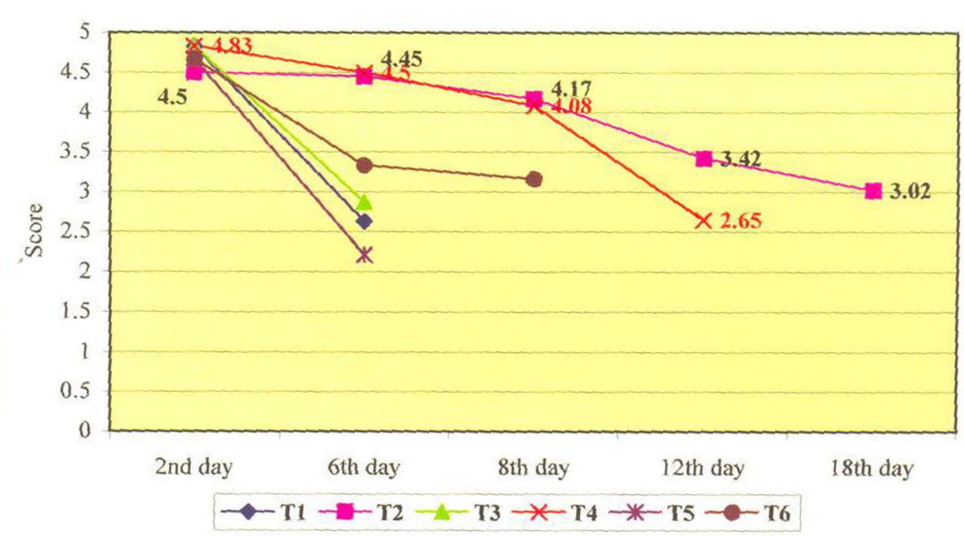


Fig. 7. Effect of light (minimal) processing and storage methods on aroma of tender coconut water (TCW)

Experiment-II. Development of Technologies for utilization of fresh tender coconut husk

A. Utilisation of TCH for compost making

This experiment was attempted considering the importance of recycling of agricultural waste as an organic manure in the present context of promoting organic farming. A sizable quantity of fresh tender coconut husk is wasted every year. If a viable technology is developed that will have a good field application.

From the observations noted at monthly intervals up to fourth months it revealed that the rate of decomposition was not satisfactory and it was practically nil in any of the treatments. Reduction in lignin content of the samples was from 11.02 to 9.85 per cent only and that of the C/N ratio was slightly below the original values. Treatments combiniations of, husk + cow dung in room condition, (T_1) and husk alone in room condition, (T_3) was showing slightly low value of C/N ratio (though not significant) as these treatments had added nitrogen with it. Added nitrogen had no effect as stated in the case of other crop residues by Allision and Cover (1960), Mahendrappa (1978) and Basaglia *et al.* (1992). The reason is when C/N ratio is too high added nitrogen was not effective in initiating decomposition (Fog, 1988).

For future work in this line, instead of trying with the fresh tender coconut husk for decomposition, the chopped and well dried pieces of tender coconut husk may have more response to the treatment. The well dried tender coconut husk bit can also be tried for vermi-composting.

Theradimani and Marimuthu (1991) reported 78 to 82 per cent reduction in lignin content of coir pith within a period of 44 days. This effect was not found with TCH bits may be due to the size of the samples compared to the granular and pithy nature of the coir pith particles, which limited the contact with oxygen and penetration of laccase, the lignin degrading enzymes produced by fungus, decreasing the decomposition rate.

B. Utilisation of TCH for silage making

Observations made on the qualitative aspect of tender coconut husk and the silage prepared using tender coconut husk and its level of acceptance are discussed here. The nutritive value of tender coconut husk (NFE-64.53%. ADF-23.90%, NDF 40.93% and lignin 13.90%) was comparable with any recommended fodder crop. (Mathen *et al.,* 1982). The properties of the TCH silage such as odour, acceptable range of pH and absence of any visible symptom of fungal growth in silages of combinations, TCH + Pineapple waste 25%, (T_2) and TCH + jaggery 5% (T_4) made them acceptable to the cows.

Calorific value of the silage could be increased from 2.37 k cal g^{-1} of control to 4.2 k cal g^{-1} in T_4 and 4.9 k cal g^{-1} in T_2 due to the added components and it was well above the calorific value of corn silage (2.57 k cal g^{-1}) reported by Lassiter and Hardy, (1982).

Results reported by various workers (Mathen *et al.,* 1982 and Ananthasubramanian *et al.,* 1983) on incorporating coir pith from mature coconut husk in feeding rations for calves showed that lignin content of coir pith which was ranging from 25 to 30 per cent was not affecting digestibility of the feed and the animals maintained positive nitrogen balance after the feeding trial and it was adding to the body weight gain. Hence, tender coconut husk can be considered to be more suitable for silage making as it is less matured than the full grown coconut husk with relatively lower lignin content. Results of the present study has indicated that the tender coconut husk bits after silaging was acceptable to cows indicating scope of detailed feeding trials with silaged tender coconut husk.

C. Utilisation of TCH as a component in growing medium for anthurium

There was progressive increase in plant height over the period with all treatments but there was no significant difference between the treatments. At 10^{th} month stage treatments TCH showed higher plant height (30.10 cm and 30.20 cm respectively) but statistically they were on par with other treatments. So it an be

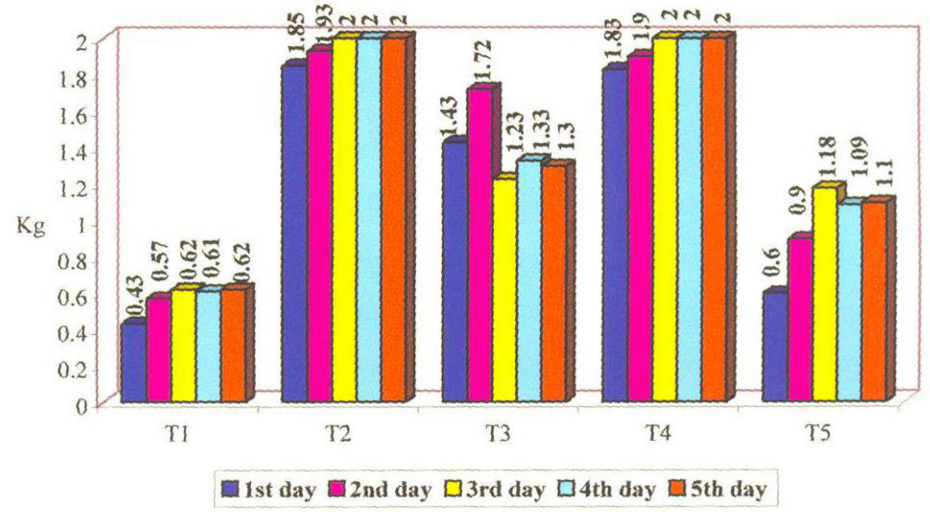


Fig. 8. Level of acceptance of different silage samples fed to the cows

assumed that TCH had the same effect in the plant height as other component such as tiles bits, charcoal, standard potting mixture and mature coconut husk.

Number of leaves produced was not influenced by any treatments as the plants were producing only one leaf/month irrespective of the treatments (Salvi, 1997). The trend was same in the case of petiole length also (18.4 cm to 23.4 cm in 6th month). But when the plants came to flowering phase there was a slight and gradual reduction in petiole length (23.4 cm to 18.5 cm) may be due to the sharing of nutrients for the production of flower stalk and flowers. In this case also the difference between treatments were not significant. Exactly similar trend was recorded in the case of leaf area index (LAI) also which was in increasing trend up to seventh month and then slowly decreased. Among the flowering and floral characters studied such as, days taken for flowering, interval of flower production, number of flowers, length of flower stalk, length of spadix and spathe size, only spadix size showed significant difference between treatments.

From the results obtained it can be concluded that TCH was as good as MCH to be included in growing medium for anthurium.

D. Utilisation of TCH as a medium of mushroom cultivation

Suitability of TCH as a substrate for growing mushroom was attempted and its efficiency was compared with paddy straw, the conventional substrate for growing mushroom.

Time taken for spawn running was ranging from 13.33 days for paddy straw + *P. florida* to 14.17 days with TCH + *P. florida*. The time taken for first harvest was ranging from 20.00 to 20.67 days and in both cases there was no significant difference between treatments. These observations are comparable with the observations made by Krishnamoorthy *et al.* (1997). As far as the time taken for last harvest TCH + *P. florida* gave significantly longer period of 48 days when compared to other treatments (39.8 to 43.3 days) which were on par. As far as yield and biological efficiency (BE) of the media are concerned treatment T_2 (TCH + *P. florida*) the media (TCH and paddy straw) were equally good. Namboodiri (1999) also reported similar results with coconut palm wastes.

Colour and appearance of mushroom produced with both media and with both species of mushroom were acceptable and were similar to their characteristics, colour and appearance. The TCH had no any undesirable effect on these characters.

Biological efficiency of both media (TCH and paddy straw) were statistically on par with the sp. of *P. sajor caju* (39.58 and 40.25 respectively). But in the case of *P. florida* paddy straw gave a significantly higher value of 42.00 against 33.17 with TCH. Namboodiri (1999) also reported that coconut waste was second to paddy straw in its biological efficiency.

Regarding taste and flavour TCH with *P. sajor caju* recorded higher score of 5 and with other treatments it was 4.8. These results confirm that TCH can be a good substrate for mushroom especially for the species *P. sajor caju*

E. Firewood value of dry tender coconut husk

Coconut crop residue is a major source of household fuel material wherever coconut is grown, it is especially true in the case of Kerala. Besides, it is used as fuel for drying copra and many other agricultural produces. It can be estimated that in India about 30 million tones of coconut waste, except trunk, is obtained as fuel material from coconut of which about 1.5 million tones is from tender coconut.

The calorific value of TCH was less than that of MCH (2.37 and 2.64 k cal g^{-1} respectively). Fire wood value of tender coconut shell (shell of minimally processed tender coconut collected and dried) had a calorific value of 3.99 k cal g^{-1} (FVI of 5840) and it was comparable with the fire wood value of other traditional fire woods which is ranging from 3.8 to 4.1 k cal g^{-1} (Shanavas 2001).

Experiment III. Pilot testing of light (minimal) processing technology

Pilot testing of minimally processed tender coconut revealed that it was acceptable to the consumers, even on 18th day of storage, similar to the whole tender coconut as far as the quality is concerned and recorded as more convenient to use (Fig. 9). In the light of this findings it will be possible to commercialise this product. By adopting this technology tender coconut consumption can be increased to many folds from the present level of 10 per cent of the total coconut production (Rethinam, 2001). It will provide employment to thousands of unemployed youths in rural and urban areas. Coconut farmers also will be benefited by ready market for their produce without any economic loss as both tender coconut and ripe nuts are getting the same farm price. Exploiting this potentialities, marketing of minimally processed tender coconut in all tourist centres, way-side restaurants, parlours and even in star hotels, the coconut scenario can be freed from any economic crisis. It can be taken up in a big scale under organized/co-operative sector by unemployed youth or even by coconut farmers co-operatives units, by availing financial assistance from banks and other related organizations.

Pilot study conducted for T.P. technology for tender coconut revealed the following results (Fig. 10 and 11).

44% of the consumers opined as very good and 52% opined as satisfactory.

70% of the consumers noted as similar to the fresh tender coconut

100% of the consumers recorded as similar to synthetic drinks.

48% (18th day) to 96% (2nd day) of the consumers were willing to purchase it if available in the market.

100% of the consumers opined as convenient to use the product.

Pilot testing study of LP tender coconut was successful and encouraging and it can be recommended for commercialization.

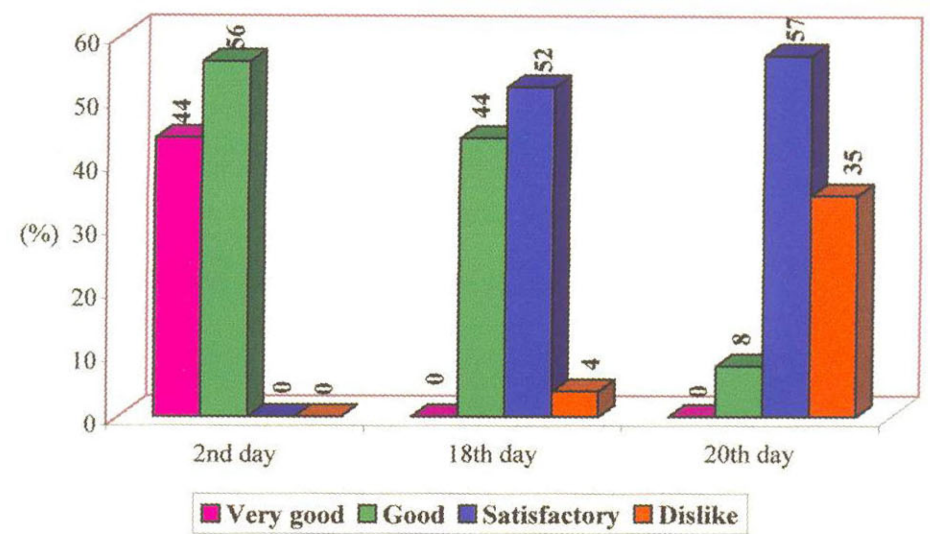


Fig. 9. Overall response in pilot testing of LP tender coconut

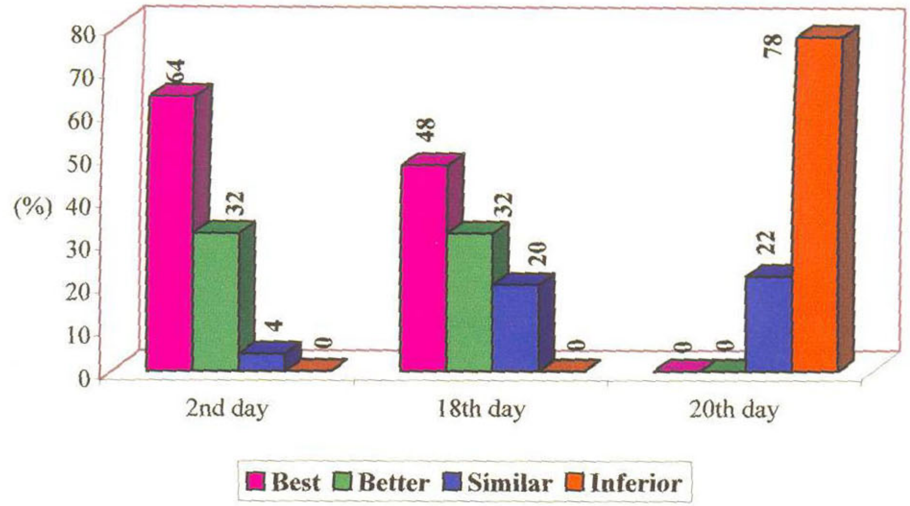


Fig. 10. Comparison of LP tender coconut with other synthetic drinks

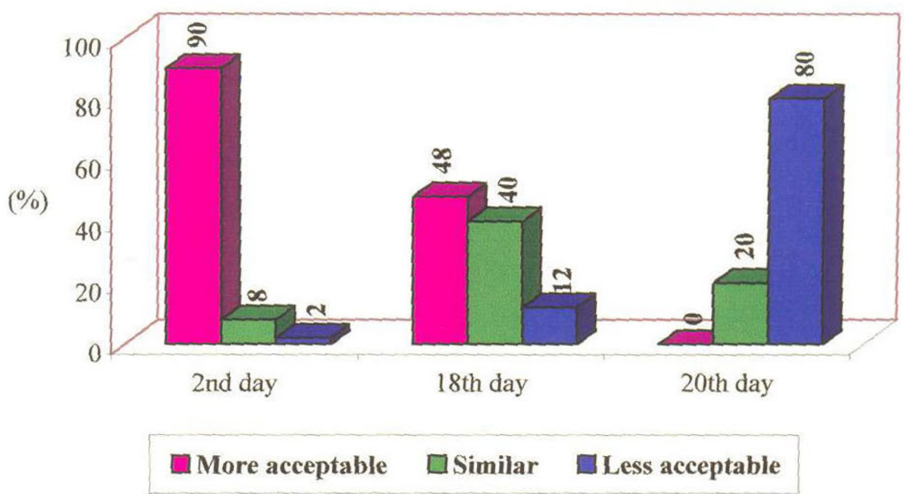
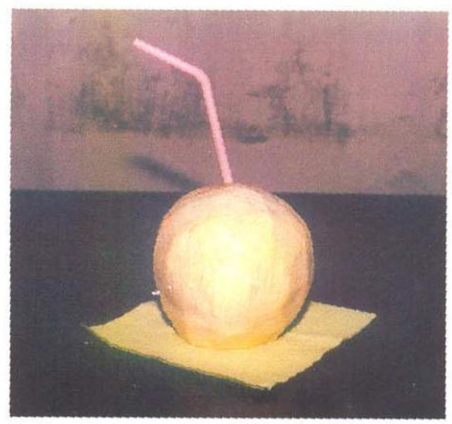


Fig. 11. Comparison of LP tender coconut with other fruit juices like orange, grapes and pineapple

Summary



6. SUMMARY

The present study on the development of an integrated light (minimal) processing technology for tender coconut and tender coconut husk based products was carried out at the College of Horticulture, Vellanikkara, Thrissur during 1999-2001.

In this programme, efforts had been made to standardize the minimal processing and storage methods for tender coconut involving removal of husk, chemical treatment, packaging and low temperature storage to increase the storage life. The most suitable treatment was subjected to pilot testing studies to assess the consumer acceptability. The tender coconut husk chopped out while minimal processing was also subjected to various value addition. Given below are the summary of findings.

The prime objective of the study was to make the tender coconut a RTS chilled beverage which is more handy and convenient to use extending shelf life without affecting its quality. Economic and convenient transportation, minimum waste at the consumption point were also had been given due importance.

The bulky nature of the tender coconut makes it inconvenient to store under refrigeration to extend the shelf life and to serve as chilled RTS beverage.

Transporting of tender coconut to distant market in its natural bulky form is not economic and convenient and it may also cause quality deterioration. When it is in the minimally processed condition more number of tender coconut can be accommodated in refrigerated containers/vans and make the transportation convenient and economic. The objective of reducing the waste at consumption point is also achieved.

The objectives had been achieved by the minimal processing methods by which the weight and volume of the tender coconut was reduced to 47.8 per cent and

44.7 per cent respectively, of the whole tender coconut. As 78.96 per cent of the total husk trimmed off through minimal processing the waste at consumption point was reduced to 21.04 per cent.

Storage life could be extended up to 18 days without having significant reduction in any of the qualitative parameters. All the varieties tried were similar in trend for these characters.

The best storage method was packaging of LP nuts with ventilated LDPP cover with 40 ventilated holes and keeping under refrigerated condition.

Under refrigerated condition, PLW was negligible under the best storage method and hence quality could be retained for a longer period up to 18^{th} day of storage.

There was a gradual reduction in TSS of TCW with storage period and it was comparatively slow in the best treatments under refrigerated condition. It was reduced from 4.9 to 4.6 ^{o} Brix on sixth day of storage in treatments other than under refrigerated treatments. In treatments under refrigerated condition the level of TSS was maintained at 4.9 to 4.3^{o} Brix at 18^{th} day.

There was slight change in acidity of TCW with storage period and it was not significant with respect to the best treatment irrespective of the varieties.

TSS/acidity ratio was maintained acceptable in best treatment under refrigerated condition and in other treatments it was going down reducing the acceptability.

Scoring of sensory parameters such as appearance, taste and aroma of TCW showed that in each case these values were above satisfactory level till the end of storage period of 18^{th} day in best treatment (LP nut under refrigeration).

Therefore, it could be concluded that treatment T_2 (LP nut with ventilated package and cool storage) was superior and can be recommended for minimal processing of tender coconut.

The rate of decomposition of TCH was not satisfactory in any of the treatments. Lignin content was reduced from 11 to 9.85 per cent only and C/N ratio was reduced from 55.00 to 44.81.

TCH was found to contain (on dry weight basis) 64.53 per cent digestible carbohydrate (NFE) 7.2 per cent crude protein and 1.73 per cent crude fat indicating its suitability as an supplementary feed.

Calorific value of the TCH could be increased from 3.37 to 4.2 k cal g^{-1} in silage combination of TCH + Pineapple peels and 4.9 k cal g^{-1} in the other combination of TCH + jaggery. These two silage combinations were found fully acceptable to the cows. By adopting this technology, the TCH waste now thrown as a waste can be best utilized as a quality feed for cows. However, its adaptability as an alternative and regular feed is to be assessed before a feed recommendation is made.

TCH can be considered as a good component in growing medium for anthurium as it was found equally effective in growth, flower production and floral characters, to other components such as mature coconut husk, charcoal, tiles bits etc. Adopting this technology will help saving the mature husk which can otherwise be utilized for coir extraction.

Suitability of TCH in comparison with paddy straw as growing medium for mushroom was proved good as there was no significant difference, in qualities studied with both media including biological efficiency (BE) with mushroom *P. sajor caju*. The technology for using the TCH as substrate for mushroom mushroom cultivation can be popularized.

Fire wood value of TCH was next to that of MCH, whereas for tender coconut shell (3.99 k cal g^{-1}) it was equal to that of traditional fire woods (3.8 to 4.1 k cal g^{-1}). It showed that the waste of LP nut could be converted as fuel materials of high value which will increase the income of minimal processing unit.

Pilot testing of minimally processed tender coconut revealed that it was acceptable to the consumers as a convenient coconut RTS beverage. The acceptability level was similar to that of whole tender coconut and also opined as superior to other synthetic drinks. The product can be recommended for commercialization.

Conclusion

Coconut scenario in India is always under an economic crisis due to frequent price fluctuation as the coconut price is ruled by coconut oil price. In this context product diversification in coconut is of prime importance.

The LP technology standardized being a farm level low cost technology it can assure a competitive price to the farmers at farm gate. The garbage problem at the consumption point is properly taken care of by the LP technology by converting it into value added products.

As the product has registered an appreciably long period of storage life with convenience in transportation, chilling and consumption popularizing the product in all potential areas covering tourist points, star hotels, restaurants and other public places can improve the tender coconut consumption many folds. It is also helpful in creating employment opportunities for rural and urban youth

As future line of work, it is suggested to develop some mechanical devices for easy trimming of the tender coconut husk. Conducting studies on the effective transportation of LP tender coconuts in insulated vans and containers to facilitate over seas marketing can also give a boost to this sector. A detailed feed trial on TCH silage is also will be highly beneficial in finding a value addition for TCH.

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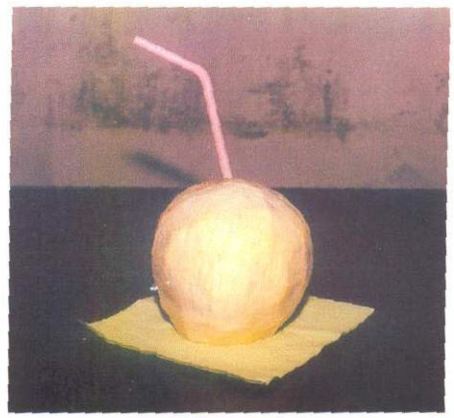

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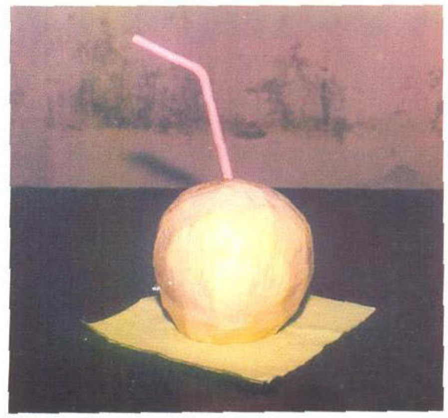
* Originals not seen

Appendices



APPENDIX - 1

Whether parameters for the year 2001

Month	Temperature (°C)				AVP (mm mercury)	Mean RH%	RF mm	Total RF mm	Mean Wind Speed Km/hr	Total evapo-ration mm	Rainy days	Total rainy day	Mean sunshine hrs.	Total sunshine hrs.
	Highest Max.	Lowest Min.	Mean Max.	Mean Min.										
Jan.	35.2	20.5	32.6	23.2	15.0	56	0.0	0.0	8.5	199.3	0	0	8.0	249.4
Feb.	36.2	18.4	34.5	22.9	18.2	67	12.2	12.2	4.2	142.0	1	1	8.0	223.4
Mar.	37.0	22.4	34.9	24.0	21.3	69	4.4	16.6	4.1	171.0	0	1	8.2	252.8
Apr.	38.4	22.5	34.2	24.7	21.3	75	243.1	259.7	3.5	128.2	8	9	6.5	193.7
May	34.5	22.0	32.2	24.5	23.6	81	192.6	452.3	3.3	121.7	14	23	6.4	198.4
June	32.8	21.6	28.4	23.1	21.3	87	676.2	1128.5	3.4	87.8	23	46	1.9	57.6
July	31.0	21.4	29.0	22.7	20.1	85	477.7	1606.2	3.5	83.5	19	65	2.4	73.5
Aug.	30.6	22.0	27.5	23.1	21.0	87	256.2	1862.4	3.6	96.7	21	86	3.6	112.3
Sep.	33.0	20.0	30.8	23.2	21.0	79	206.1	2068.4	3.2	124.0	6	92	5.3	160.3
Oct.	33.2	21.6	30.7	23.0	22.0	81	215.8	2284.3	3.1	105.9	8	100	4.7	145.5
Nov.	33.0	21.4	31.6	23.1	19.4	72	115.8	2400.1	4.9	122.2	6	106	6.2	184.9
Dec.	32.8	17.8	31.3	22.2	16.5	60	0.0	2400.1	10.0	181.7	0	106	8.1	252.4

APPENDIX - 2

Soil characters of Vellanikkara Campus

Organic Carbon	1.59 %
pH	5.29%
Available N Kg. ha^{-1}	425 - 452
Available P Kg. ha^{-1}	11.2 - 14.5
Available K Kg. ha^{-1}	430 - 443

APPENDIX - 3

Changes in nut water composition during the development of coconut

Genotype	Age of nut (months)	Vol. of water (ml)	pH	Acidity (KOH/l)	Total sugars (%)	Reducing sugars (%)	N (mg/l)	P (mg/l)	K (mg/l)	Ca (mg/l)	Mg (mg/l)	S (mg/l)	Fe (mg/l)	Mn (mg/l)	Zn (mg/l)	Cu (mg/l)
W.C. Tall	4	75	3.5	117	0.8	0.78	32	48	1113	206	40	6.5	21.63	91	12.2	0.73
	6	310	4.7	108	3.3	3.0	195	118	5320	578	176	10.1	16.54	82	18.3	0.85
	8	230	5.5	99	5.6	5.4	432	186	7300	994	262	35.4	11.54	49	18.0	0.80
	10	145	5.9	85	3.4	1.6	336	140	3260	312	102	47.8	8.69	31	10.3	0.53
	12	100	6.1	78	1.8	0.3	299	108	3181	269	106	48.0	8.40	30	7.4	0.34
D x T	4	102	3.1	121	0.7	0.7	42	40	1225	194	42	7.2	22.69	84	12.2	0.92
	6	460	4.6	111	3.1	3.0	202	120	6014	542	182	10.5	14.89	78	16.8	0.98
	8	290	5.2	102	5.1	5.0	486	194	7900	1020	219	33.8	10.68	52	17.0	0.92
	10	205	5.5	92	3.1	1.8	348	152	3380	298	108	45.4	6.49	32	10.0	0.64
	12	190	5.8	84	2.2	0.3	290	97	3370	262	106	50.1	7.20	33	6.9	0.36
T x D	4	95	3.3	117	0.7	0.7	37	44	1108	212	43	5.8	22.13	99	10.0	0.92
	6	315	4.9	107	3.2	3.0	199	131	5120	593	180	9.8	15.82	84	17.1	0.96
	8	320	5.8	101	5.8	5.5	415	192	7326	1045	248	36.4	12.13	45	16.9	0.89
	10	125	5.9	88	3.5	1.5	332	148	3180	298	114	50.1	7.82	29	11.1	0.64
	12	90	6.0	80	2.1	0.4	295	103	3192	273	112	48.2	7.50	30	7.0	0.30

Gonzalez, 1993

APPENDIX - 4

Changes in sugar content of coconut water during maturation

Maturity stage	Total sugar (%)	Reducing sugar (%)	Non-reducing sugar (%)
I	4.8	4.0	0.8
II	5.7	4.4	1.3
III	4.6	3.2	1.4
IV	3.8	2.4	1.4
V	3.1	2.0	1.1
VI	2.8	0.6	2.2
VII (M)	2.0	0.2	1.8
VIII (M)	2.0	0.2	1.8

M: mature nuts

Jayalakshmi, *et al.*,1988

APPENDIX - 5

Amino acid composition of coconut water (% of total protein)

Alanine	2.41
Arginine	10.75
Aspartic acid	3.60
Cystine	0.97 – 1.17
Glutamic acid	9.76 – 14.5
Histidine	1.95 – 2.05
Leucine	1.95 – 4.18
Lysine	1.95 – 4.57
Proline	1.21 – 4.12
Phenylalanine	1.23
Serine	0.59 – 0.91
Tyrosine	2.83 – 3.00

Gonzalez, 1993

APPENDIX - 6

Vitamins of B Group in coconut water

Nicotinic acid	0.64 microgram / ml
Pantothenic acid	0.52 microgram / ml
Biotin	0.02 microgram / ml
Riboflavin	0.01 microgram / ml
Folic acid	0.003 microgram / ml
Thiamine	Trace microgram / ml
Pyridoxine	Trace microgram / ml

Gonzalez, 1993

APPENDIX - 7

Composition of Nutrients in water and kernel of coconut

Material	Moisture (%)	Protein (%)	Fat (%)	Carbohydrate (by diff.) %	Crude Fibre (%)	Ash (%)
Water from Unripe nuts	95.01	0.13	0.12	4.11	--	0.63
Water from ripe nuts	91.23	0.29	0.15	7.27	--	1.06
Kernal from Unripe nuts	90.80	0.90	1.40	6.30	--	0.60
Kernal from ripe nuts	46.30	4.08	37.29	11.29	3.39	1.03

Subrahmanyan & Swaminathan, 1959

APPENDIX - 8

Protein and energy content of some silage

Type of silage	Drymatter	Feed basis		Dry basis	
		Crude protein	TDN	Crude protein	TDN
Maize silage	30	2.5	20	7.5	60
Grass silage	27	3.2	15	10.1	50
Sorghum silage	29	2.3	17	7.1	53

Subashchandran, 1969

DEVELOPMENT OF AN INTEGRATED LIGHT (MINIMAL) PROCESSING TECHNOLOGY FOR TENDER COCONUT AND TENDER COCONUT HUSK BASED PRODUCTS

By

K. V. SUBRAMANIAN

ABSTRACT OF THE THESIS

Submitted in partial fulfilment of the requirement for the degree of

Doctor of Philosophy in Horticulture

Faculty of Agriculture

Kerala Agricultural University

Department of Processing Technology

COLLEGE OF HORTICULTURE

VELLANIKKARA, THRISSUR - 680 656

KERALA, INDIA

2004

ABSTRACT

Investigations in developing an integrated light (minimal) processing technology for tender coconut and tender coconut husk based products were conducted at College of Horticulture, KAU, Vellanikkara, Thrissur – 681 565.

Objectives of the study was to standardise some methods for minimal processing and low temperature storage to extend the shelf life of tender coconut enabling to serve as a chilled RTS beverage. To find out some method for effective utilization of TCH (Tender Coconut Husk) was another objective of the study.

Popular varieties such as WCT, COD, COD x T, T x GB were subjected for the study. Minimal processing involving trimming of the husk, treating with a solution of KMS 0.5% and citric acid 0.5% for 5 minutes, packaging in LDPP cover of 0.025 mm with 40 ventilation holes, kept under refrigerated condition was found to increase the shelf life of L.P. nut up to 18 days without quality deterioration and acceptance. Changes in TSS and acidity of LP nut under refrigerated condition was very minimum registering their values 4.07^{o} Brix and 0.112% respectively on 18^{th} day.

On a pilot testing study it was found that the consumers accepted the product up to 18^{th} day of storage and recorded it as more convenient to use.

TCH was found useful as a medium for mushroom growing, as a component of medium for growing anthurium and also for preparation of silage. Decomposition of TCH was very poor.

For mushroom growing TCH registered a BE of 39.58% with *P. sajar caju*. As a component in growing medium for anthurium TCH was equally good as MCH (Matured Coconut Husk).

Silage prepared with TCH was found to be of good nutritive value with digestible carbohydrate content of 64.53% and acceptable to the cows fed with it.

Husk and shell of tender coconut had a calorific value of 2.373 and 3.985 k cal g^{-1} respectively.